# METALLURGIA

THE BRITISH JOURNAL OF METALS

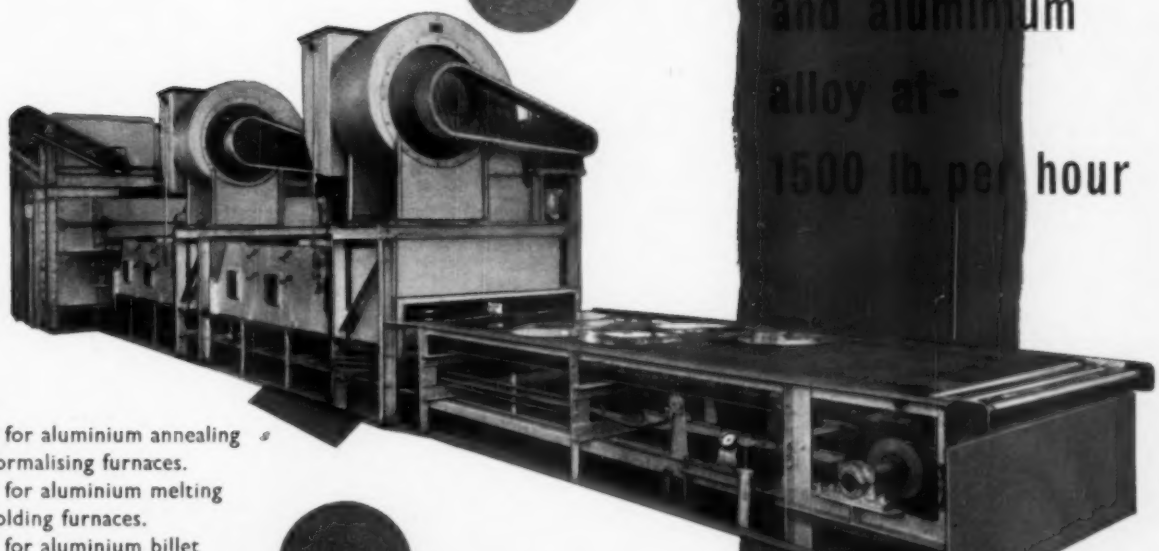
Vol. 63 No. 377 MARCH, 1961 Monthly: Two Shillings and Sixpence



FLASH

ANNEALING

aluminium
and aluminium
alloy at-
1500 lb. per hour



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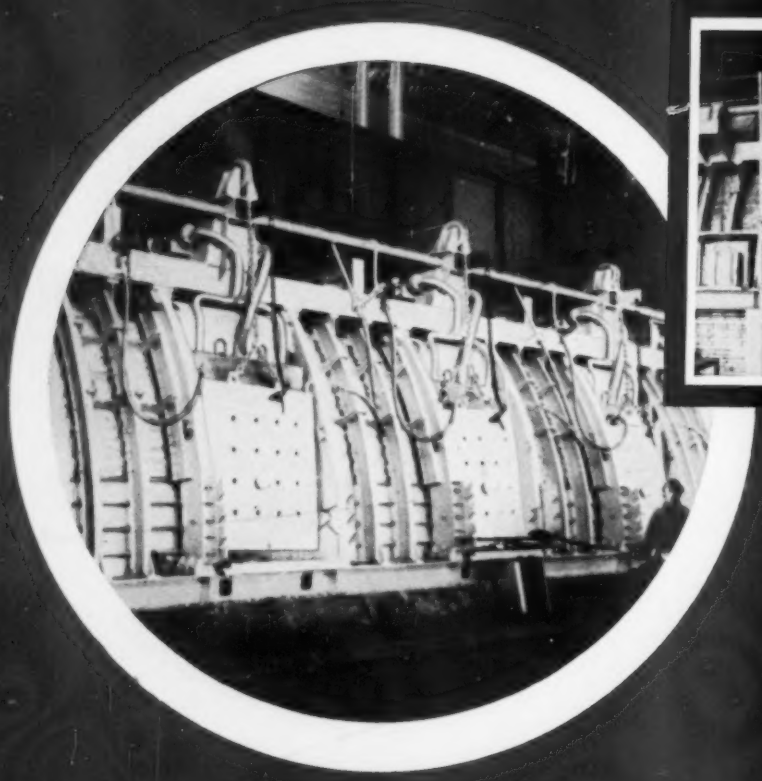

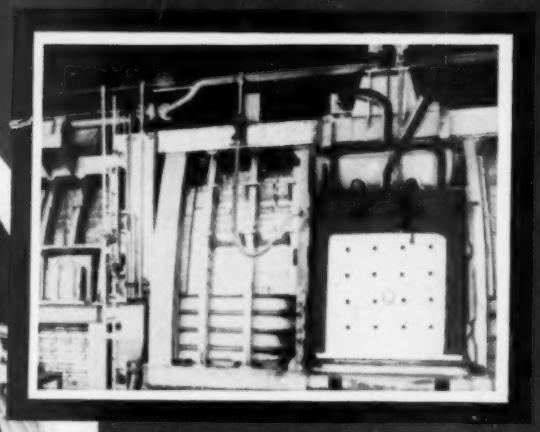

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| Maksiccar Plastic | Plastic | Heat Setting | Hand moulding or patching | 1730°C | 900°C | 1580°C | 140 | 2243 |
| Stein Sillimanite Patch | Plastic | | | | 1000°C | 1700°C | 155 | 2483 |
| Stein 73 Plastic | Plastic | | | + 1750°C | 1000°C | 1800°C | 180 | 2884 |
| Maksiccar Fire Putty | Plastic | Air Setting | Hand moulding or patching | 1350°C | 500°C | 1100°C | 140 | 2243 |
| Stein Chrome Patch | Semi-Plastic | | | + 1750°C | 600°C | 1500°C | 200 | 3204 |
| Maksiccar Patch | Plastic | | Ramming or patching | 1600°C | 600°C | 1550°C | 135 | 2162 |
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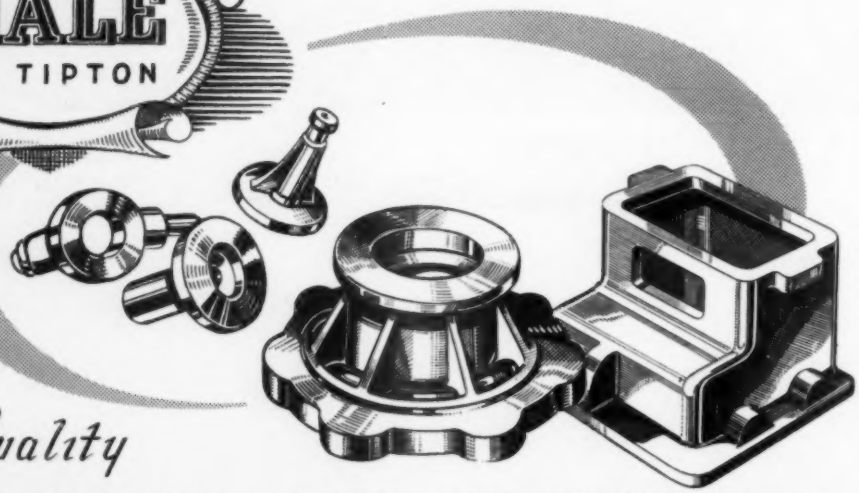

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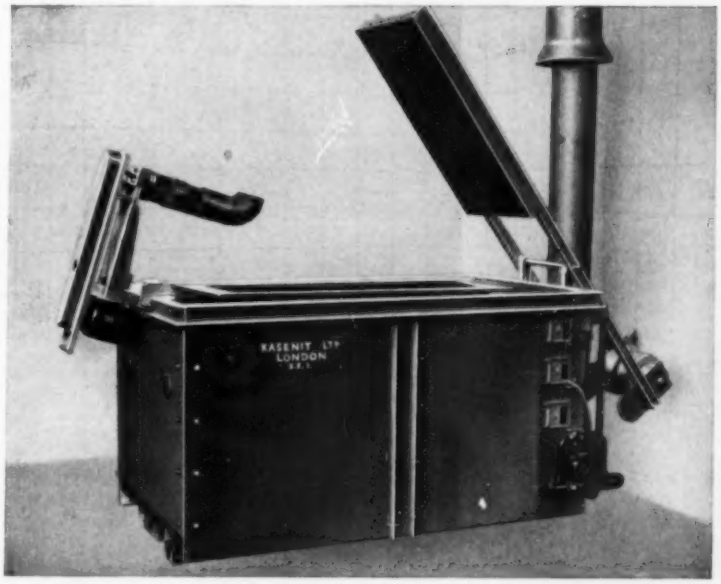


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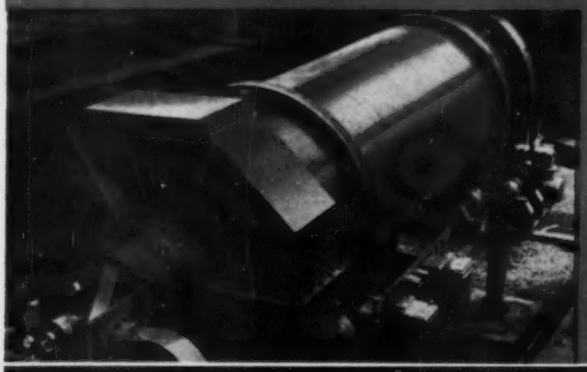
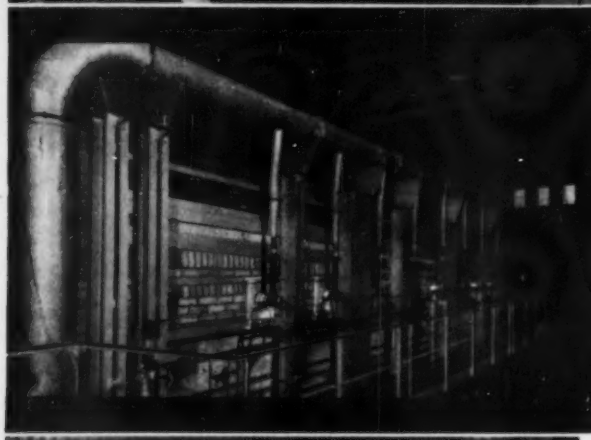
*Brochures are available to illustrate the full range of Stordy-Hauck burners.*



### ASPHALT PLANT

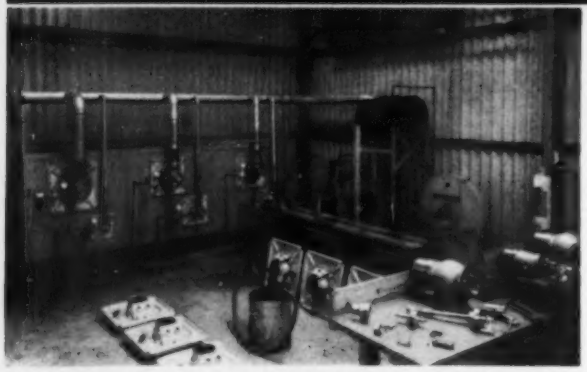
A Stordy-Hauck self-proportioning oil burner applied to a rotary dryer and asphalt plant.

This burner more than meets the operating temperature range required for varying materials handled.



### GLASS MELTING

Stordy-Hauck self-proportioning oil burners are fitted to this Hartford Empire Unit glass melting installation, comprising 18 burners all under full automatic control.



### TESTING

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# Spode's BONE CHINA

***"The nearest ever to the fine Oriental porcelain yet devised for practical use . . ."***

*The old way — loading now-obsolete coal-fired kilns — a dirty, laborious and unhealthy operation.*

JOSIAH SPODE (1733-1797) persevered with hundreds of experiments before he finally discovered the wonderful translucent bone china—the nearest ever to the pure Oriental porcelain devised for practical use. In fact his introduction of bone china has been of outstanding importance in the annals of the English fine china trade. One of his eminent contemporaries, Monsieur Alexandre Brongiart, a Director of Sèvres, wrote at the time "Spode produced a better porcelain than any other which has hitherto been made in England."

The marketing of this new Spode chi a became largely the responsibility of William Copeland, a Staffordshire-born tea broker who was living in London. Soon a firm Spode-Copeland partnership emerged of such an extent that the descendants of William Copeland have continued in the family business in an unbroken sequence to this day.

Nowhere in England, the home of the bone china trade, is fine bone china better produced than at W. T. Copeland's works. Within these works are produced dinner services in bone china, highly decorated with gold and colours, which sell for hundreds of pounds, and yet, also bearing the Spode insignia of manufacture, come tea services and dinner services which grace. the tables of people in every walk of life.

But tradition is one thing and modern production is another. The world demand for Spode table ware had increased rapidly in the post-war years and in 1958 Mr. Spencer Copeland, the Managing Director, outlined the Board of Directors' decision. He said, "The outstanding feature is to be a tunnel kiln to fire biscuit bone china; it must be capable of firing, to a high standard, a volume of china varying from our present production to three times this amount." This was the problem presented to the Spode technical team headed by Mr. Ian Forse, the Manager. After investigation he approached a leading firm of kiln designers and builders and they agreed that there was no kiln which would give all the results Spode required. They interchanged ideas and a gas-fired tunnel kiln was developed to meet all their needs. It was christened "The Jubilee Oven" to commemorate its being lighted by the Lord Mayor of Stoke-on-Trent in the Jubilee Year.

*The new way — the Pottery Queen lighting the new gas-fired tunnel kiln at the Spode factory. She is assisted by Mr. I. Forse, the Spode Works Manager.*

Those particularly interested in firing pottery will be interested to know that the kiln is fired by gas and is 138 feet long, holding twenty-nine trucks of ware. The early preheat zone has sufficient controllable exhaust off-takes to make the early stages of the kiln practically dead when firing on a slow schedule. The loading height is flexible from two feet to three feet. The bottom burners have duplicate orifices, the higher or lower respectively being used to suit the loading height. The exhaust ports can also be adjusted in the same way. Gas is boosted to about 1 lb. per sq. in. pressure and is burnt through three tiers of burners with sixty-six burners on each side. These burners are divided into a total of six separate groups, five groups being automatically controlled. The burners in the top half of the kiln are separately controlled from those in the bottom

*The new gas-fired kiln for firing biscuit bone china; capable of meeting present production and three times this amount economically.*

half. There are three sections of cooling zones each comprising five separate controllable cavities. A Contravec heat control system at each end of the kiln provides a crown blast which prevents the heat from drifting to either end of the kiln. The peak temperature of the kiln is 1265°C and it takes about thirty hours to reach its peak.

In fact, the Spode Directors demanded flexibility of the fuel and of the kiln, together with the advantages of continuous running, for they required a kiln to fire from 700 dozen to more than 2,500 dozen articles a week, a most unusual demand. It has been specially designed to meet the most exacting circumstances for which no standard kiln would cater. It replaces the last of the old coal-fired bottle kilns which required two weeks from the time the work was put in until the time it was taken out. By comparison this new gas-fired tunnel kiln requires three days and gives an infinitely greater control of the temperature/time schedule than ever possible before, and the fuel cost is only half of that when coal was used.

There are, of course, a number of fuels which could have been used for this new advanced tunnel kiln. However, the Manager, Mr. Forse, said, "We selected gas because of its flexibility—it is possible to get more 'trim' on the individual flames in the kiln without the necessity of removing banks of heating elements." This flexibility, which enables the temperature in the various zones of the kiln to be closely controlled, coupled with low operating costs, ultimately led to the decision to use gas as the fuel. The West Midlands Gas Board produce in this area gas particularly suitable for firing the fine bone china manufactured by the Spode Company. Indeed, the ware can be fired in direct-fired kilns, in many cases being unprotected by saggers. The Spode Works use more than 150,000 therms of gas per quarter. They use other fuels as well, but, when it came to firing their newest and most advanced tunnel kiln, they chose gas.

*Part of the well-known Crimson Lancaster bone china dinner service made by W. T. Copeland & Sons Ltd.*

That the traditions of Josiah Spode are still maintained is appreciated when one walks round the showrooms of the Spode Company. Accompanying a selection of table ware there is a card bearing the following caption—"The Duke of Edinburgh prize for elegant design was awarded to Neal French Des.R.C.A. and David White, designers of the Spode Apollo Table Ware made by W. T. Copeland & Sons Ltd., and chosen for one of the eighteen Design Centre Awards in the competition held in 1960." This is not a design competition restricted to pottery, but is applicable to any industrial product. And now this Apollo Table Ware is being sold to all parts of the world as a modern example of the traditional bone china emanating from the researches of Josiah Spode.

Spode is not an isolated example. In fact, the development of the pottery load is one of the outstanding success stories of the modern gas industry. Today there are many miles of gas-fired tunnel kilns in existence which have replaced the old smoky coal-fired bottle kilns. Completely smokeless in operation, they have literally changed the whole atmosphere of the Potteries, once notorious for dust and grime. The new tunnel kiln workroom at Spode provides pleasant, airy conditions comparable with those in the most modern light engineering works. No longer are its operatives old men at forty. At work and at home they are now enjoying the benefits of clean air—thanks to gas.

The Industrial Gas Engineers of the West Midlands Gas Board worked closely with Mr. Forse during his development of the kiln. This is just one example of the way in which Area Gas Boards collaborate with their consumers and exchange ideas for the ultimate benefit of all industrial users of gas.

*Part of the Spode Apollo Table Ware awarded the Duke of Edinburgh prize for elegant design in 1960.*

*Scottish Gas Board, Edinburgh.*
*Northern Gas Board, Newcastle-upon-Tyne.*
*North Western Gas Board, Manchester.*
*North Eastern Gas Board, Leeds.*
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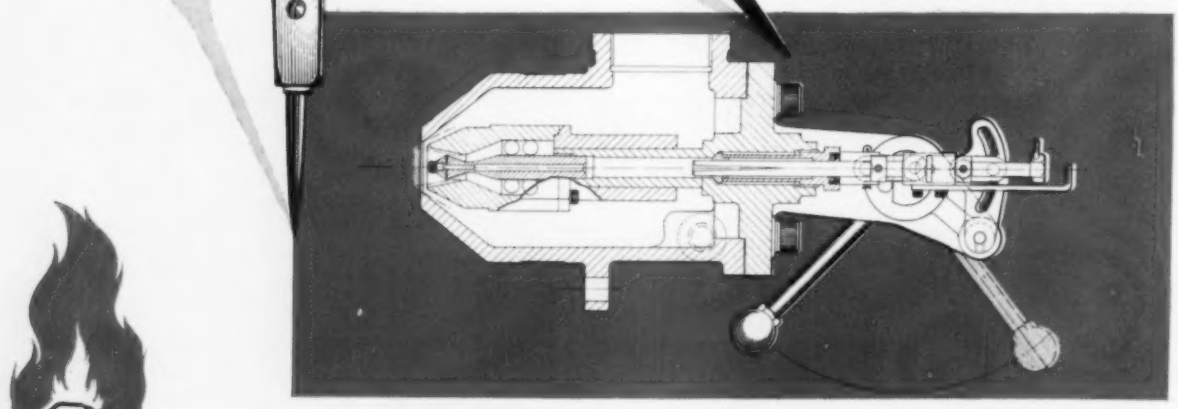

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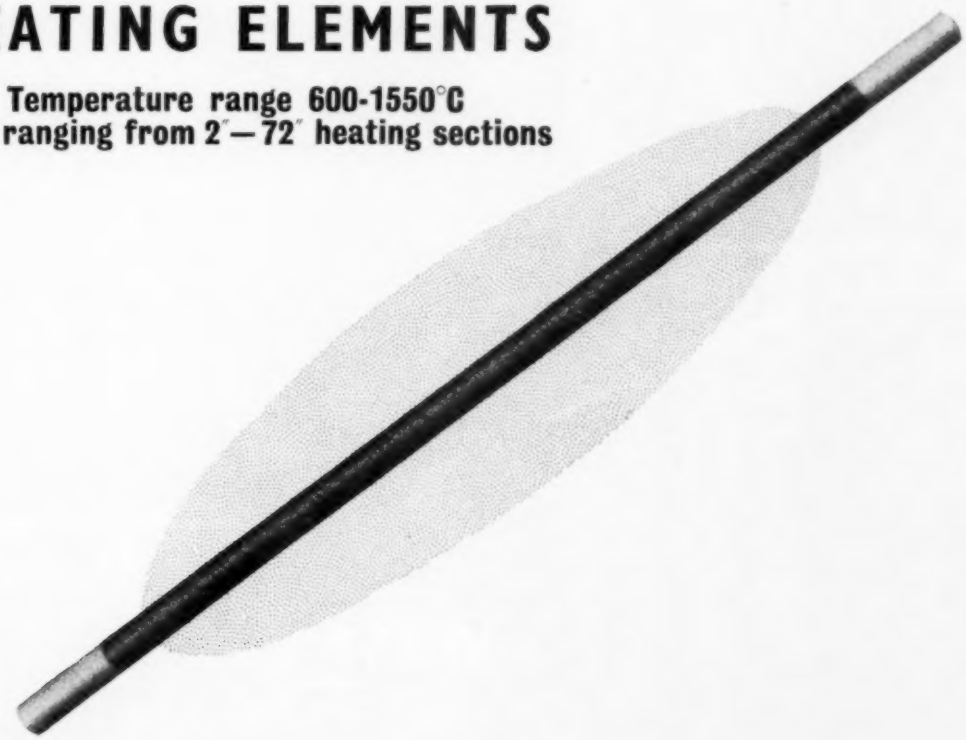

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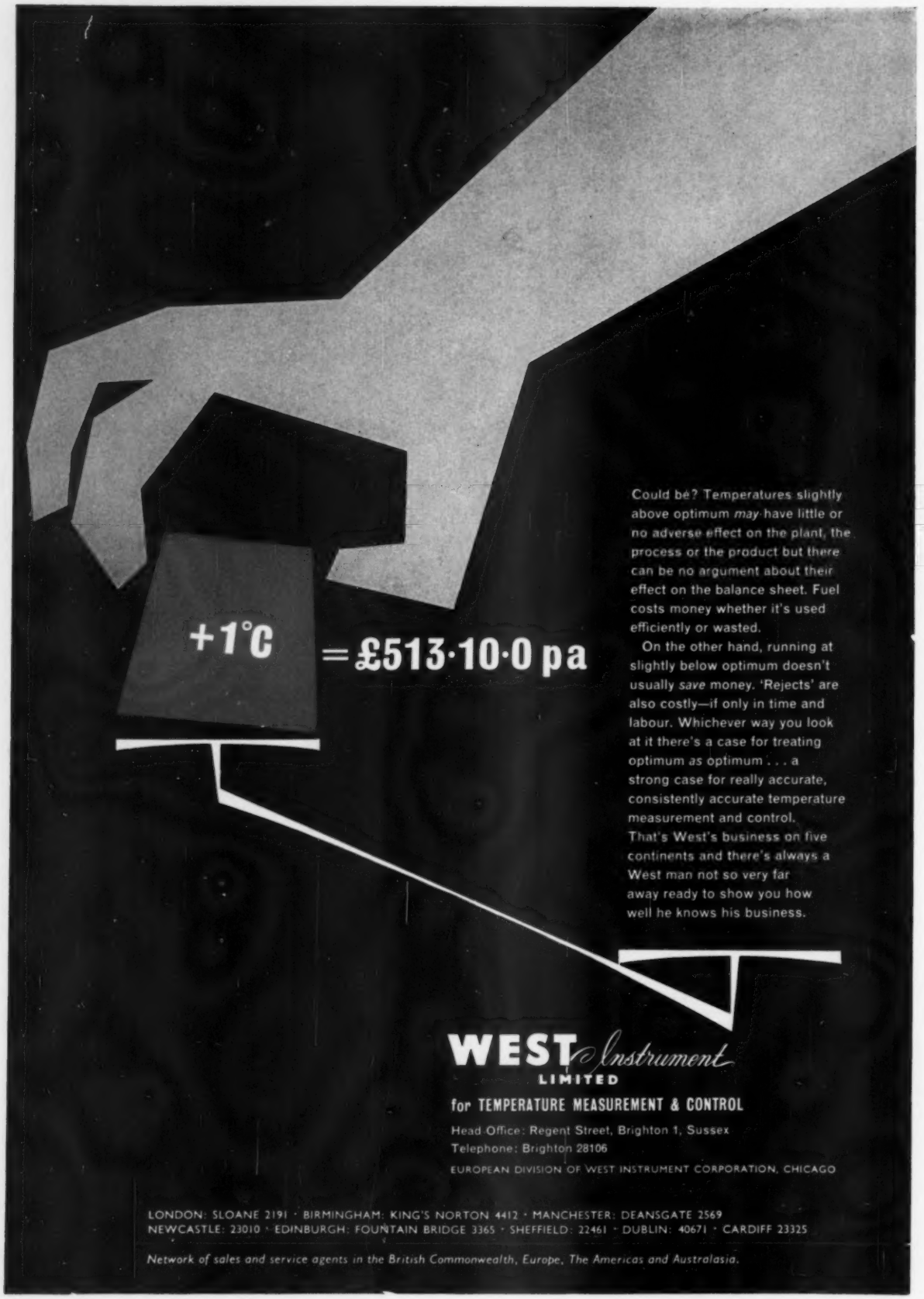


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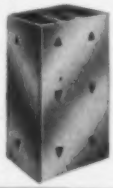
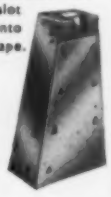
*Covered by British Patent No.'s 546,220 and 749,491*



**FERROCLIP SUSPENSION**

This method allows the brick to be suspended from the end. The Ferroclip hanger slot may be moulded into any roof or wall shape.

*Covered by British Patent No.'s 546,220 and 600,630*



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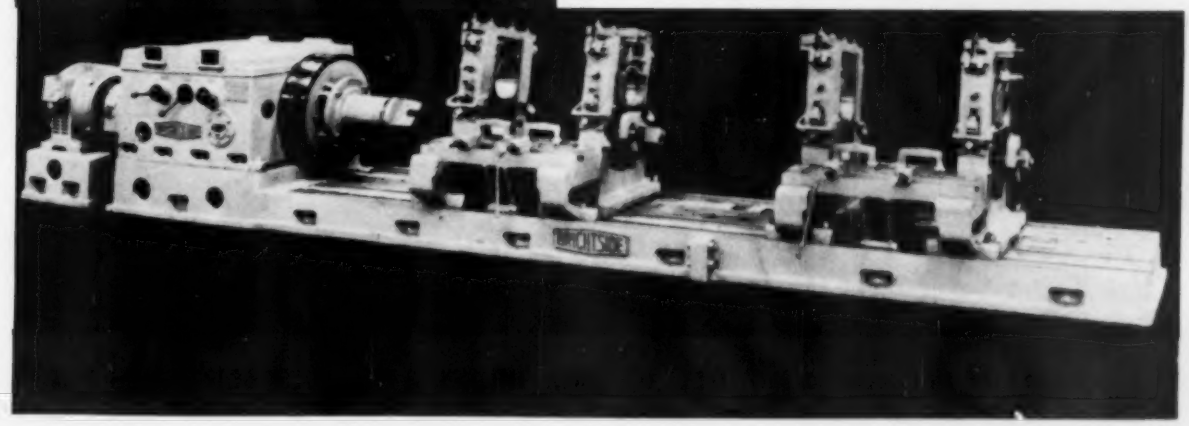

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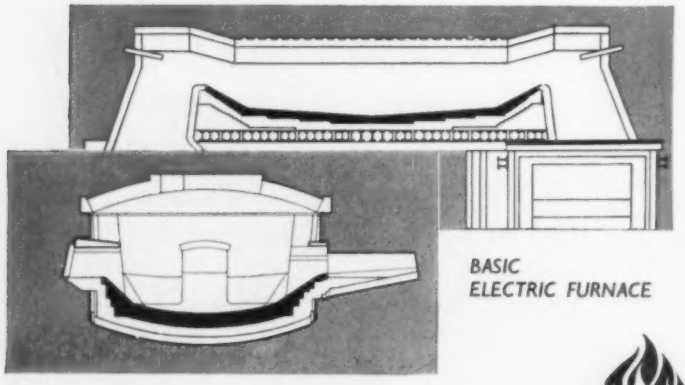

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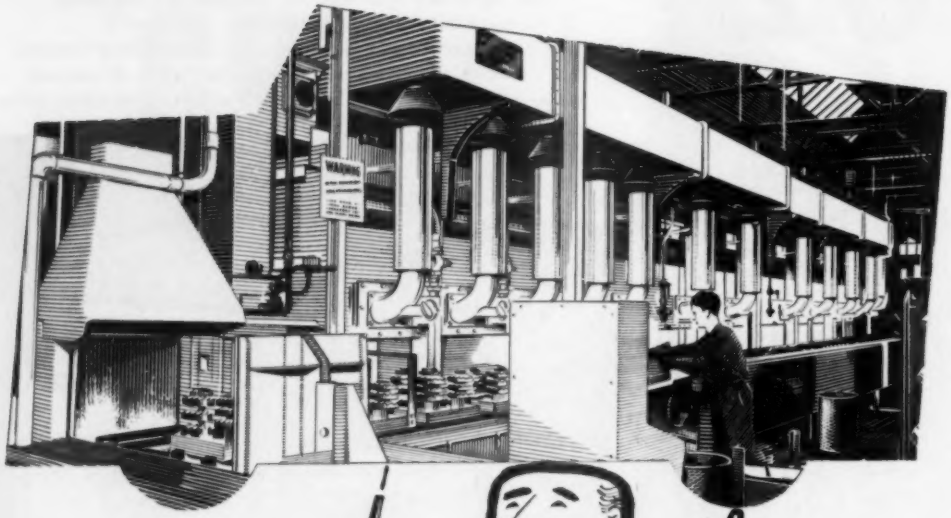
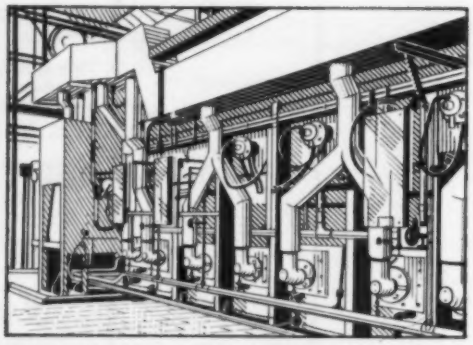


carries weight in the Motor Industry



*These illustrations, by courtesy of Ford Motor Co. Ltd, show two of many continuous gas carburizing furnaces installed at their Dagenham factory, using endothermic atmospheres produced from PROPAGAS.*

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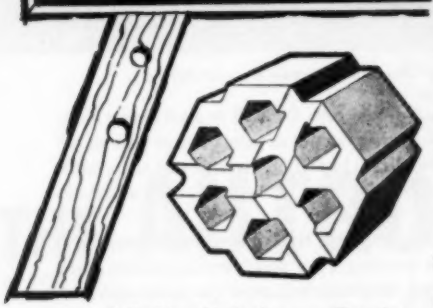

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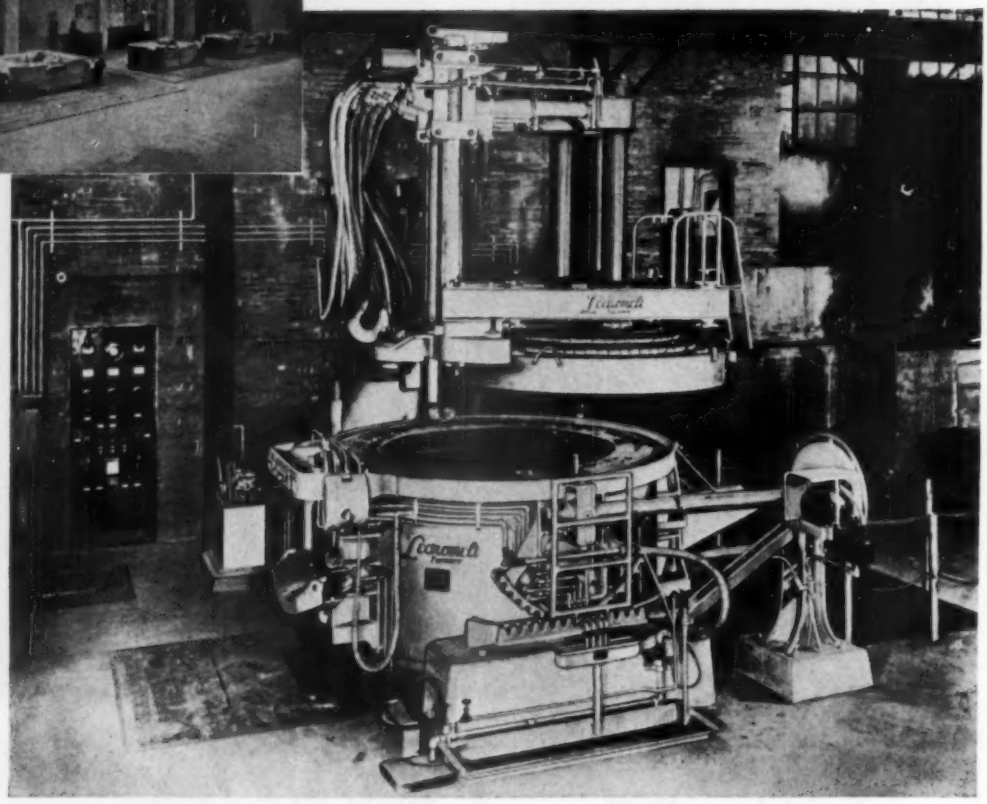
GWB

DEMAG

Lectromelt

*Demag high-frequency induction furnace installation at a steel making plant, incorporating two 1 ton capacity furnaces, two 660 lb. capacity furnaces, and one 110 lb. capacity furnace.*



*A 3 ton capacity Lectromelt arc furnace of 9' 0" diameter shown with roof swung ready for charging.*

High Speed and High Output are the key features in the medium and smaller range of furnaces offered by G.W.B. Furnaces Ltd. Many years are behind both the Coreless and Arc Furnaces of Demag and Lectromelt designs.

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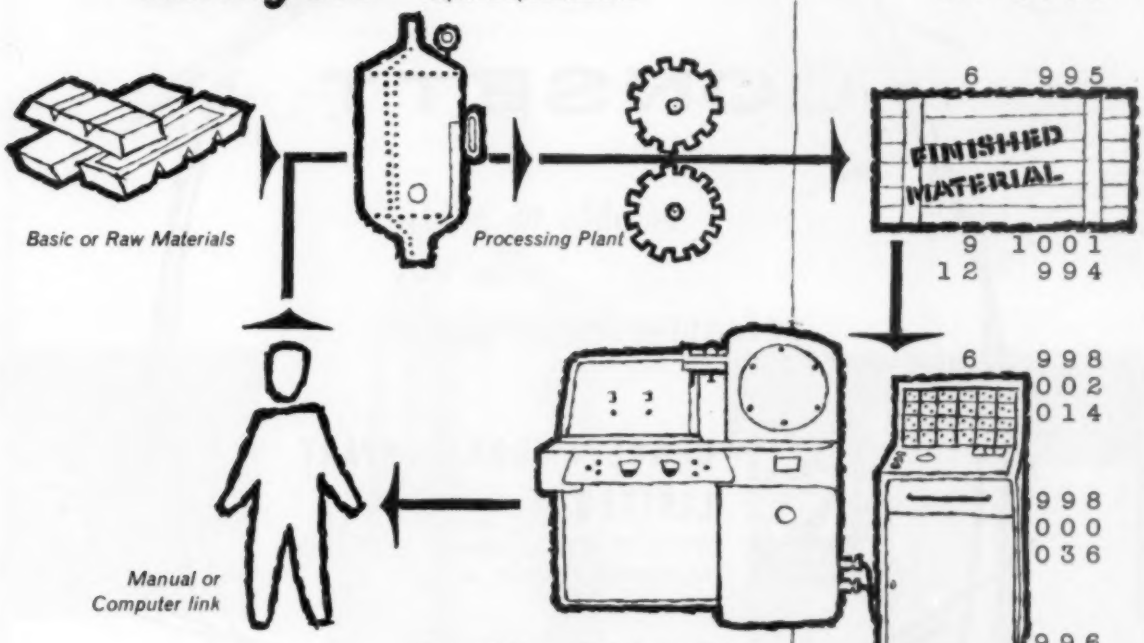


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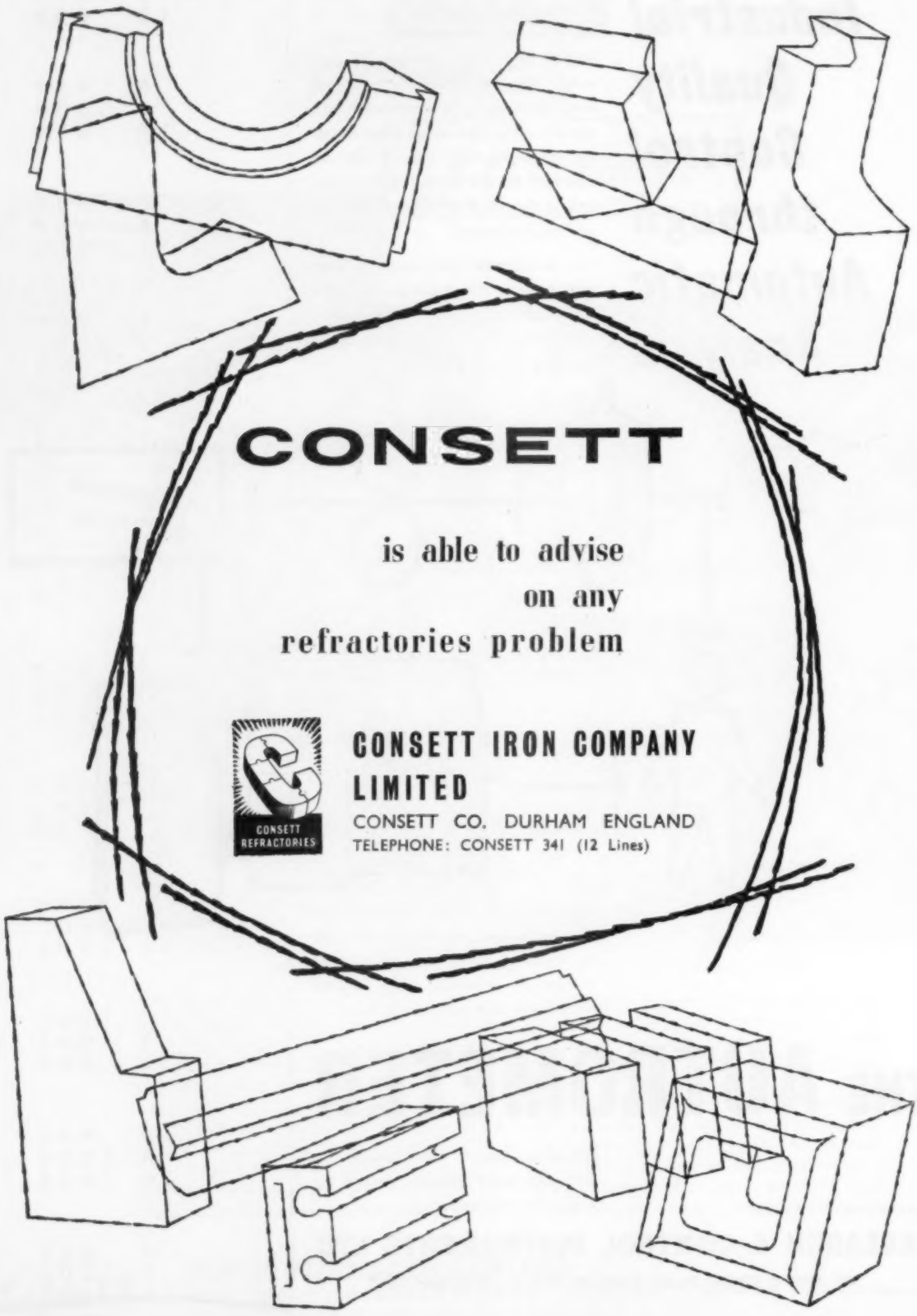
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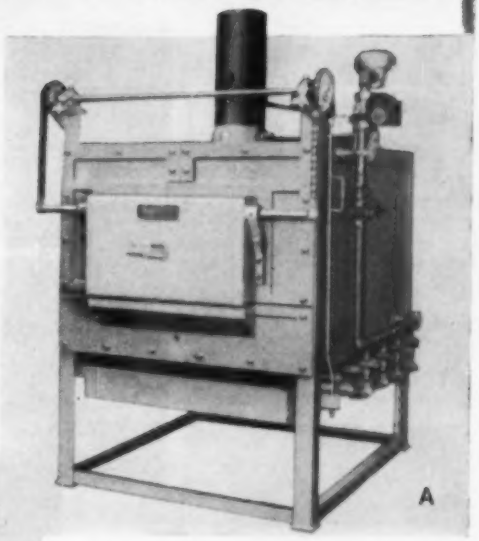
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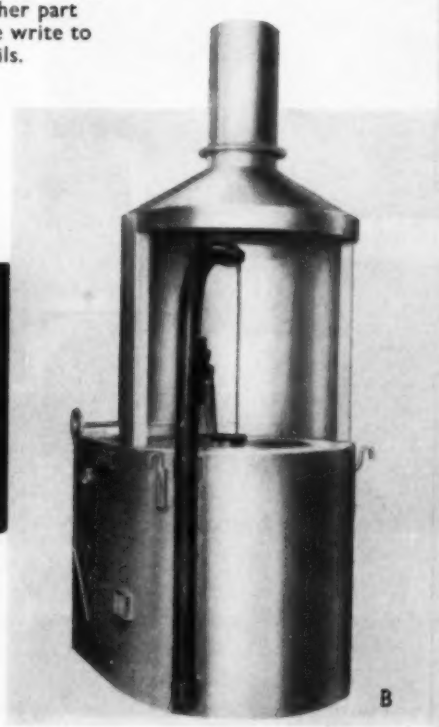
B

C

***What the illustrations show:***

A.—'Hynor' Oven Furnace.
B.—Liquid Bath Furnace.
C.—Twin Chambered High Speed Steel Furnace.

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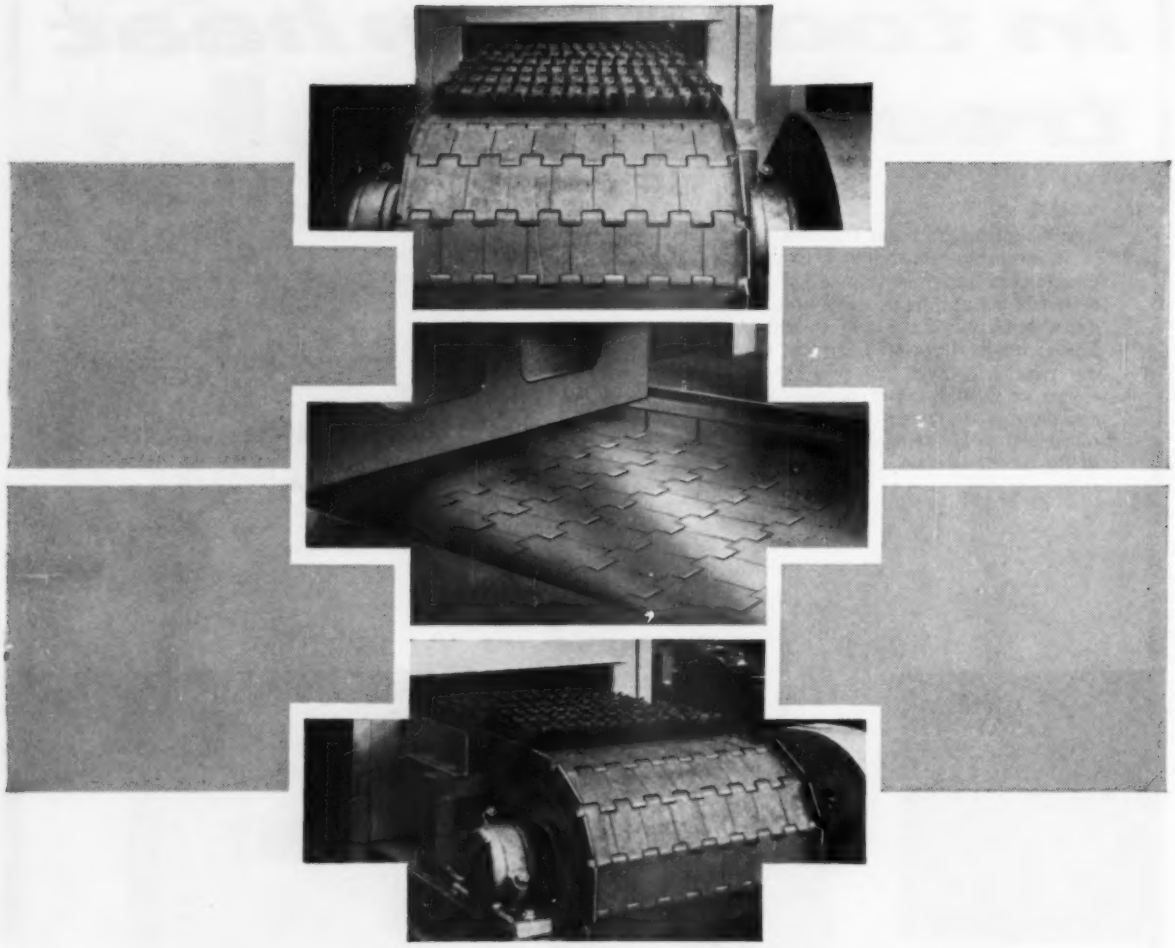
# A link with accuracy and finish



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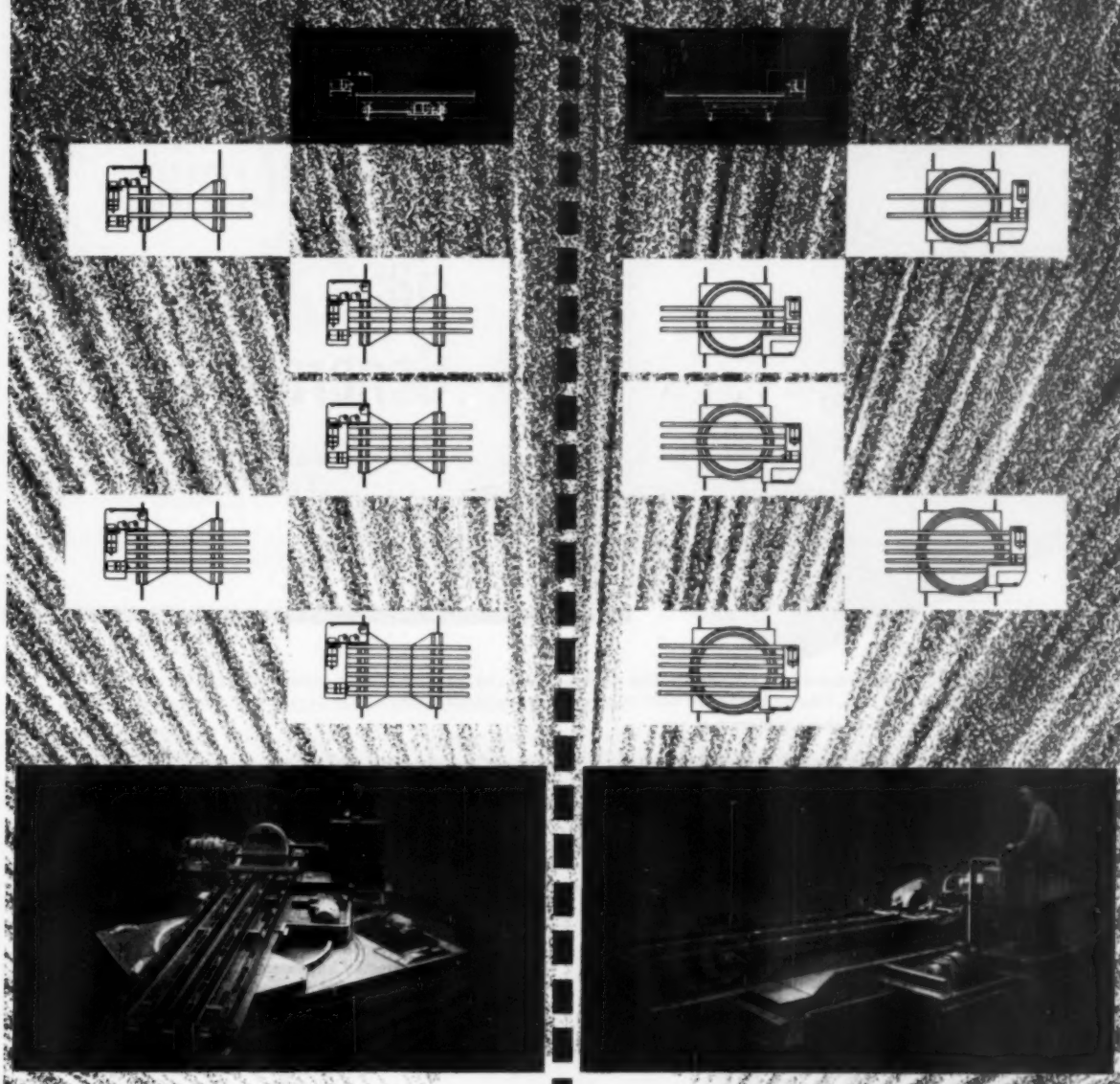





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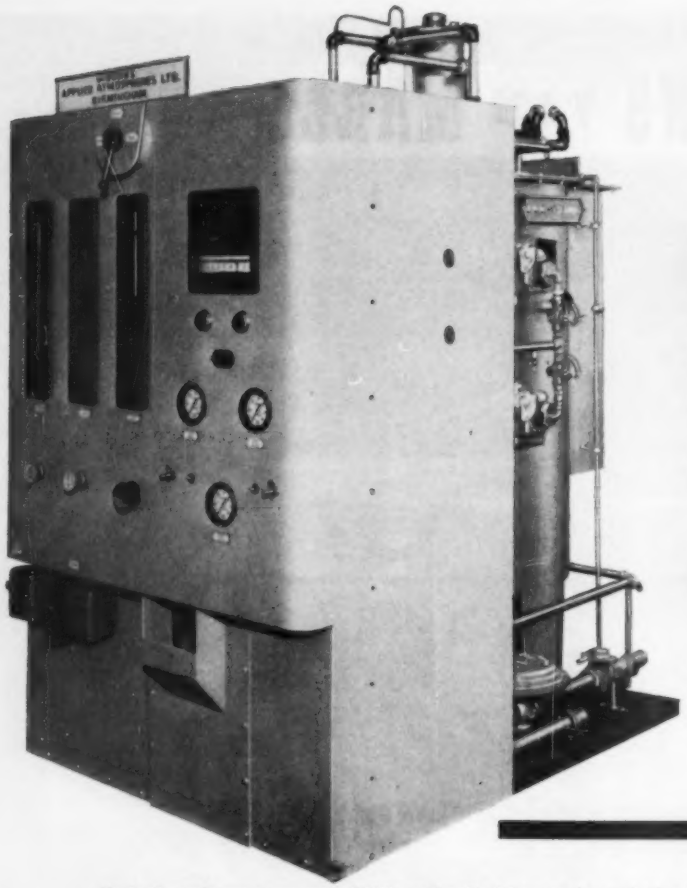

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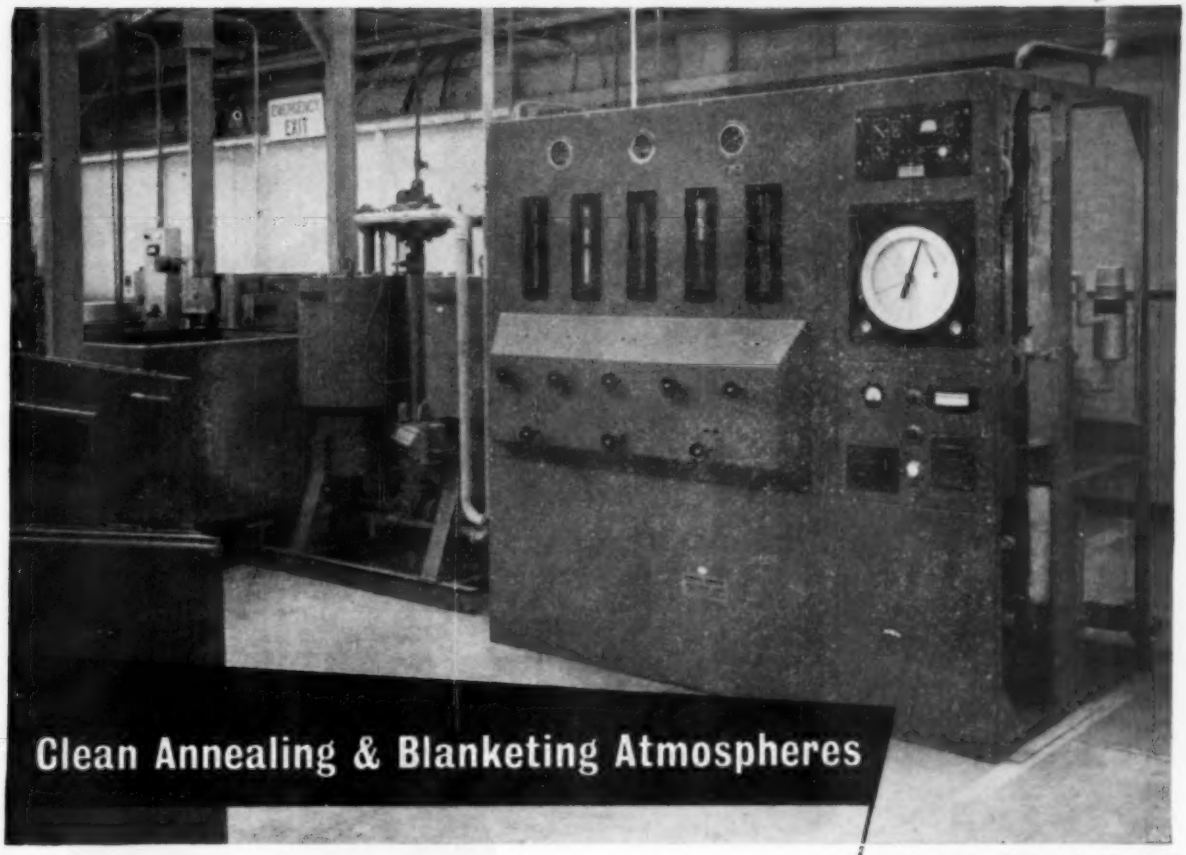


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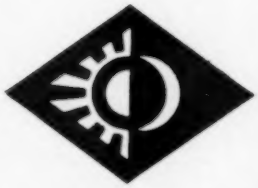

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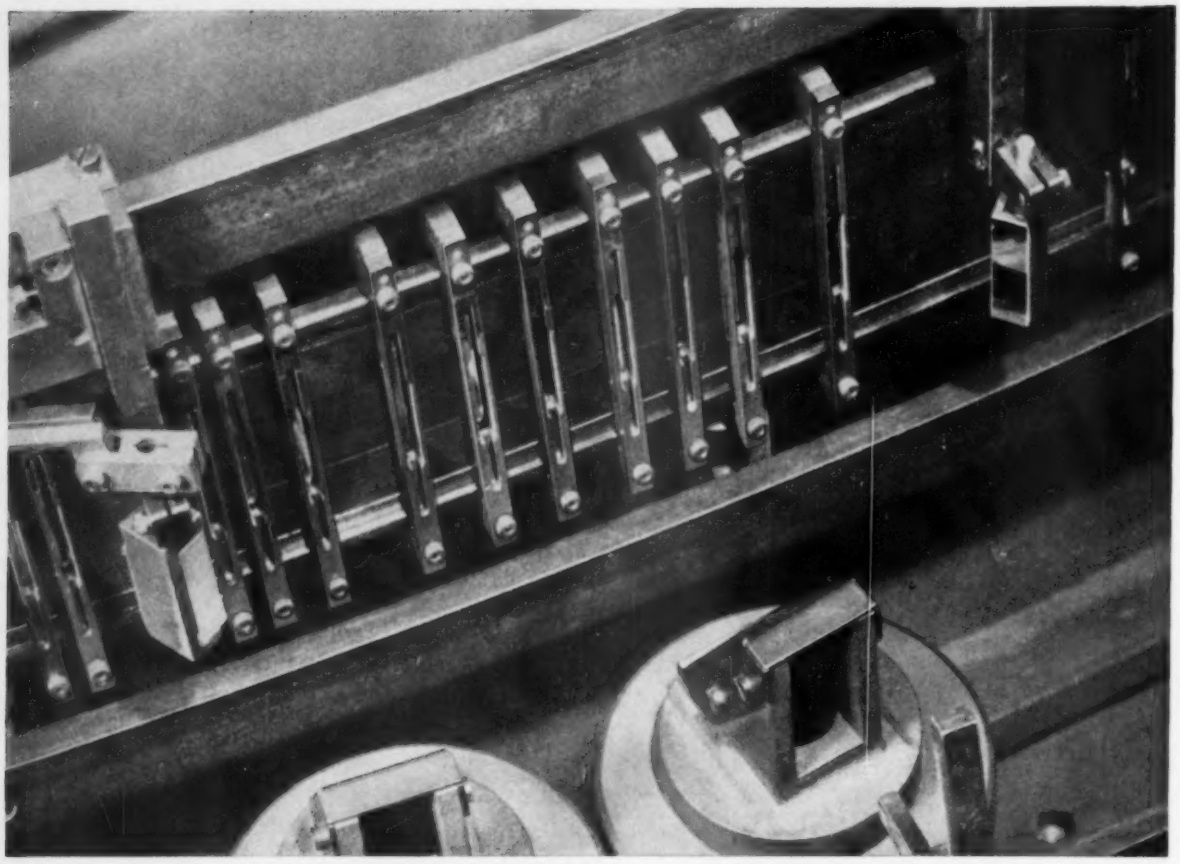

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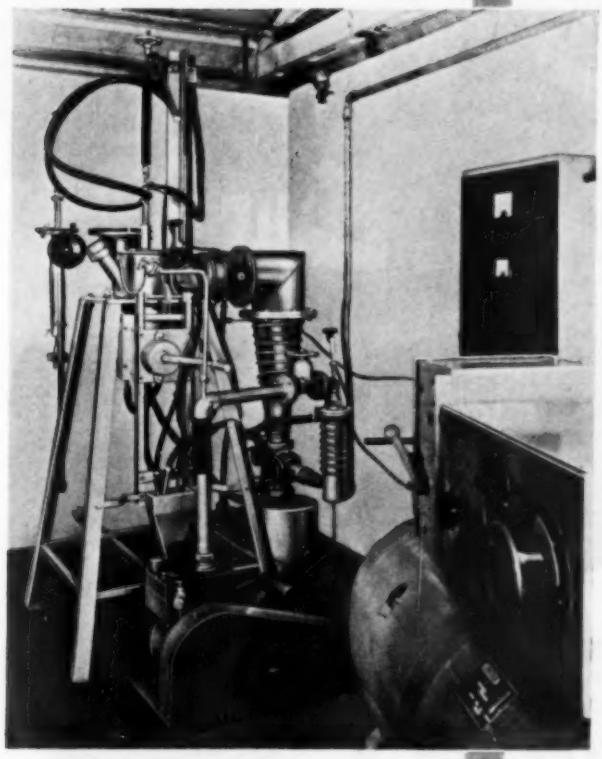

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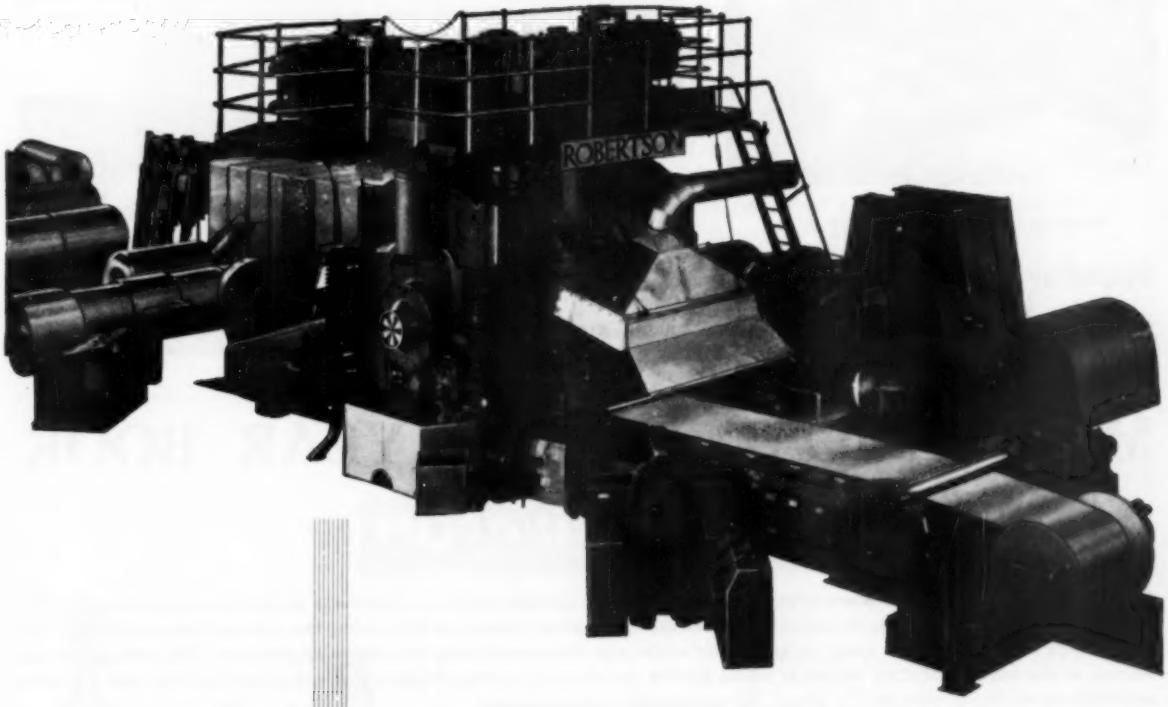


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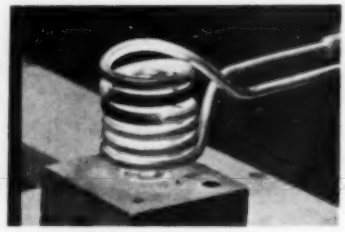

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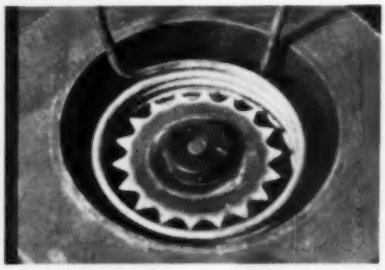

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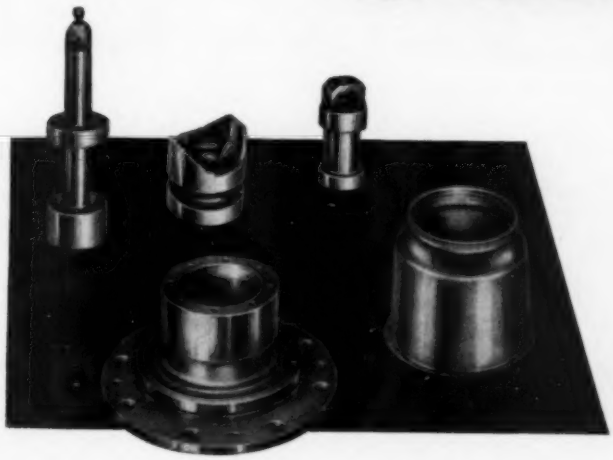

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THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

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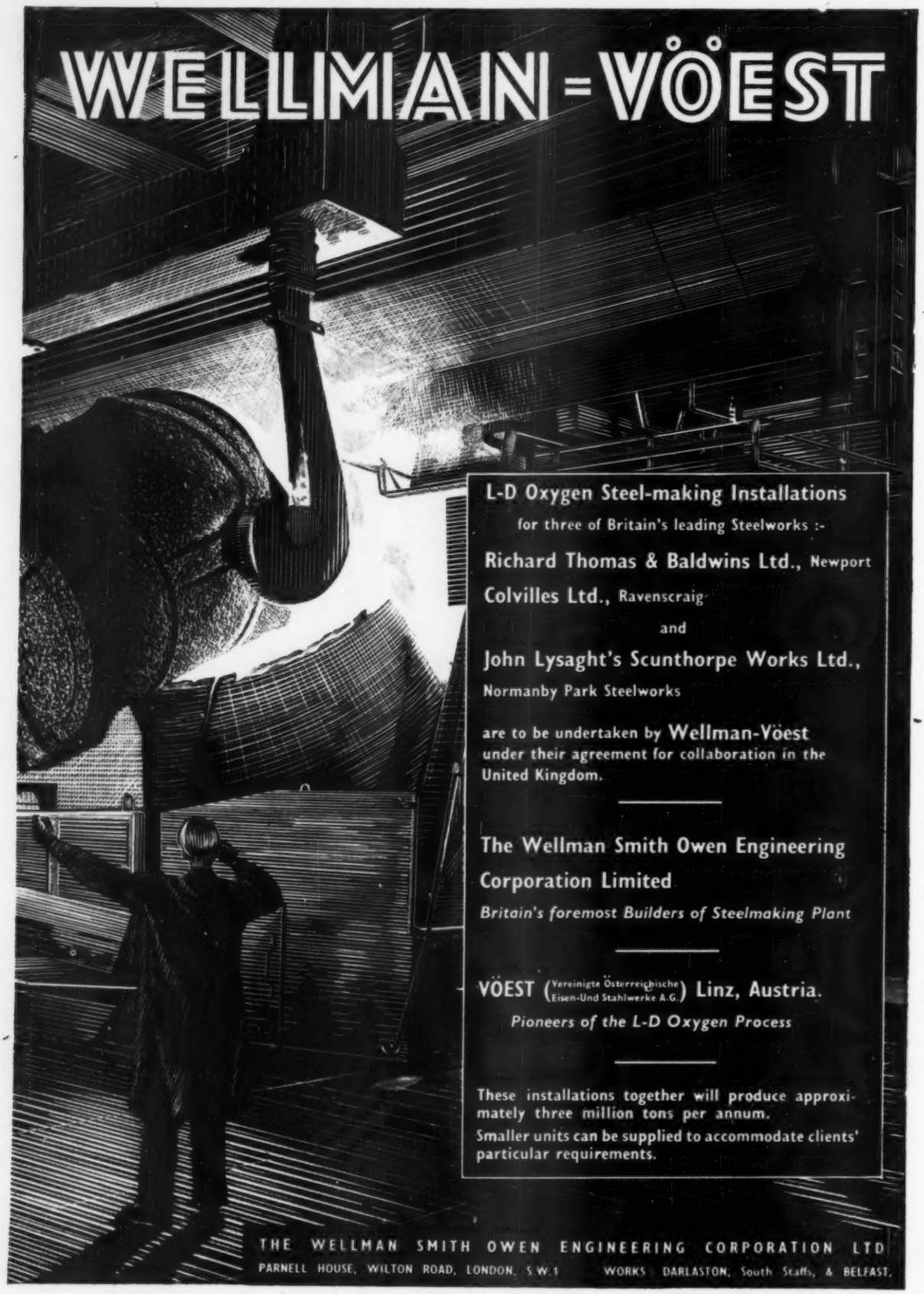


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# METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

MARCH, 1961 Vol. LXIII. No. 377


## Steel and Nuclear Power

MENTION of the metallurgical aspects of nuclear power production immediately calls to mind metals such as uranium, plutonium, beryllium and zirconium, whose importance lies in their suitability for use as fuel elements and canning materials. In view of the "publicity" given to these "rare" metals, it may come as a surprise to many that not only is the U.K. Atomic Energy Authority among the largest users of steel, but the properties of steel used for pressure vessels has been a limiting factor in the design of these structures. The U.K.A.E.A. usage of stainless steel has amounted to some 14,000 tons at a capital value of £9 million, and for their own reactors they have used about 17,000 tons of mild steel. This is, of course, additional to that used in power plants in course of construction by private consortia on behalf of the Central Electricity Generating Board. These facts were given by Sir Leonard Owen C.B.E., Member for Production of the U.K.A.E.A., in an address at a meeting of the British Nuclear Energy Conference at the end of last year. Much of this steel is for orthodox constructional purposes, for which run-of-the-mill products are perfectly satisfactory, but in at least two instances there was a call for steel to meet special requirements.

The separation of plutonium from irradiated fuel involves the use of strong nitric acid at boiling point, and it was therefore necessary to design a chemical plant which could withstand these conditions, and which could be erected behind thick concrete shielding and never be approached again. For this purpose a new stainless steel had to be developed and tested and joining procedures established. The size of the project was so great that U.K.A.E.A. took the whole of the stainless steel output of one particular type for two years.

The other major demand was for steels for the pressure vessels of gas-cooled reactors. It had been expected that limitation on the efficiency of the plant would be set by the canning material, because of the complete novelty of the problem, but the limiting factor proved to be the steel for the pressure vessel, because the pressure at which the gas system could operate was determined by the design of the vessel. Nuclear requirements dictated the size of the vessel, which turned out to be such that site fabrication was essential. Prior experience in this field was confined to plate up to 1½ in. in thickness, and it was felt that an increase to 2 in. was as far as it was prudent to go. This decision limited the pressure to 100 lb./sq. in. The construction of Calder Hall showed clearly that large steel pressure vessels could be constructed on site in 2 in. thick mild steel, but the £200/kW. of power installed was too high a figure for commercial power production. One of the most important technical factors leading to economic improvement has been the higher gas pressure introduced progressively in the six years since Calder, but the containment of such pressures gives rise to engineering and metallurgical problems, calling for thicker plate or stronger steel.

Besides the limitation on pressure at Calder Hall, the operating temperature is below the maximum attainable with magnesium fuel element cans, because of the difficulty of providing in one steel a low temperature of transition from ductile to brittle fracture (to ease site fabrication) and adequate creep strength at the operating temperature. As no steel was available stronger than that used at Calder Hall, weldable on site, and presenting the same advantages as mild steel with its long plastic range, the design of the civil power stations had to proceed on the lines of improvement of techniques using the same materials as at Calder Hall but in greater thickness.

The use of thick plate of specified high quality can result in difficulties of supply, handling, welding and inspection, leading to adverse effects on costs and programme dates, but considerable progress has been made in overcoming them, and advances which should benefit industry in general concern ultrasonic inspection for defects and radiographic techniques for thick materials.

The danger of brittle fracture has been constantly borne in mind, and precautions have been taken to eliminate the possibility of cracking during construction on site in cold weather as a result of the additive effects of welding defects, material flaws, and locked-in stresses. Maintaining the steel above its transition temperature is the only sure safeguard, though stress-relieving greatly reduces the risk. The cumulative effects of neutron irradiation cause a rise in transition temperature—as does the stress-relieving operation—but even during shut-down the reactor temperature does not fall to the low levels encountered during construction. Nevertheless, the initial ductility of the steel must be adequate to meet not only the requirements of construction, but also the effects during shut-down of any embrittlement caused by service conditions.

The fact that pressure vessel designers and builders now consider that they know how to build vessels in thick mild steel naturally engenders a conservative attitude towards a major change. Nevertheless, careful consideration of the effect of the availability of improved steel indicates that the substitution of a 36 ton steel of 2·7 in. thickness for a 28 ton steel of 3½ in. thickness in a 250 MW. power station would reduce the cost per unit by 2½%, assuming everything else remained the same. In point of fact, easier handling, less weld metal, inspection by normal radiography might lead to further reduction, despite the need for closer control of welding procedures.

In co-operation with the steel industry, fabricators and electrode makers, the U.K.A.E.A. has initiated a programme of development to make available higher strength steel with superior creep properties. Laboratory

work has been followed by the making of full-size casts and large-scale fabrication trials, and as a final stage it is envisaged that any new steel will be incorporated in conventional structures showing analogous constructional problems to a reactor pressure vessel. In this way it is hoped to build up experience to overcome prejudice against the introduction of a new steel.

The arguments for and against the substitution of alloy for mild steel in reactor pressure vessels are so far based on opinions on one side and conservative experience on the other. The only way out of this is for designers to have a more exact knowledge of stress concentrations at changes of section, and for them to have confidence that their steels can be made consistently to narrow bands of high quality. This must rely on evidence collected and made available by the steel industry. Although the majority of the steel so far used has been made by the open-hearth process, improvements in quality which may arise from more modern methods such as electric furnace and large convertors are awaited keenly.

Sir Leonard concluded his address with a plea for the co-operation of the steel industry: "The full benefits of nuclear power cannot be realised so long as the engineer is limited by the material available to him. If suitable steels are not available he may have to explore alternative materials. The reactor designer feels entitled to look to the steel industry for a lead in the problem."

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# Meeting Diary

**4th April**

**Institute of Metals, Oxford Local Section.** Annual General Meeting followed by "Ductile Fracture," by PROF. R. W. K. HONEYCOMBE. Cadena Cafe, Cornmarket Street, Oxford. 7.15 p.m.

**5th April**

**Institute of Welding, Manchester & District Branch.** Annual General Meeting—Film Show. Reynolds Hall, Manchester College of Science and Technology. 7.15 p.m.

**6th April**

**Institute of Metal Finishing, North West Centre.** Film Show "Growth of an Electro-Deposit," by S. C. BARNES. Engineers' Club, Albert Square, Manchester. 7.30 p.m.

**Institute of Metals, Birmingham Local Section.** Annual General Meeting. College of Technology, Gosta Green, Birmingham. 6.30 p.m.

**Institute of Metals, London Local Section.** Annual General Meeting followed by "Physical Methods of Analysis for Major Alloying Constituents," by K. M. BILLS. 17 Belgrave Square, London S.W.1. 6 p.m.

**7th April**

**North East Coast Institution of Engineers and Shipbuilders.** "Oil Firing with Particular Reference to Marine Application," by G. R. GRAY. The Mining Institute, Bolbec Hall, Newcastle upon Tyne. 6.15 p.m.

**10th April**

**Institute of British Foundrymen. Sheffield Branch.** "Cost Control in the Foundry," by D. A. CROOKS. Technical College, Pond Street, Sheffield. 7 p.m.

**11th April**

**Institute of Plant Engineers.** "Welding," by F. KOENIGSBERGER. 36 George Street, Manchester. 7.15 p.m.

**12th April**

**Leeds Metallurgical Society.** "Some Aspects of the Metallurgy of Fasteners," by R. J. ALLSOP. University Staff House, University Road, Leeds. 6.30 p.m.

**13th April**

**East Midlands Metallurgical Society.** Annual General Meeting followed by "Recent Work on Cold Forming and Extrusion," by N. S. ANGUS. Derby & District College of Art. 7.30 p.m.

**Institute of British Foundrymen, London Branch (Beds. & Herts. Section).** Annual General Meeting followed by a Quiz Evening: "Fault and Cure" at W. H. Allen, Sons & Co., Ltd. 7.30 p.m.

**14th April**

**Institute of British Foundrymen, London Branch (Slough Section).** Annual General Meeting followed by a Film Evening. Lecture Theatre, High Duty Alloys, Ltd., Slough. 7.30 p.m.

**West of Scotland Iron and Steel Institute.** Annual General Meeting. "Heating and Oxidation in the Basic Open-Hearth Process," by I. M. MACKENZIE, D. HADFIELD, T. URIE and MRS. A. DONALD. 39 Elmbank Crescent, Glasgow. 6.45 p.m.

**17th April**

**Institute of British Foundrymen, London Branch (East Anglian Section).** Annual General Meeting and L. J. Tibbenham Award (Short Paper) Competition. Lecture Hall, Public Library, Ipswich. 7.30 p.m.

**Institute of Metal Finishing, London Branch.** "Plating of Zinc-Based Die-Castings," by J. EDWARDS. Northampton College of Technology, St. John Street, London E.C.1. 6.15 p.m.

**17th-18th April**

**The Powder Metallurgy Joint Group of The Iron and Steel Institute and the Institute of Metals.** Discussion on "The Appraisal of Powders for Pressing and Sintering: I—Techniques for the Evaluation of Powders; II—The Relationship between Powders and their Pressing and Sintering Behaviour." Royal Commonwealth Society, Craven Street, London W.1.

**18th April**

**Institute of Metal Finishing, Midlands Branch.** "How Much Polishing is Needed," by M. A. PRICE. James Watt Memorial Institute, Gt. Charles St., Birmingham 3. 6.30 p.m. (N.B.—This meeting has been brought forward from May 2nd—no meeting in May).

**Institute of Metal Finishing, South West Branch.** Annual General Meeting and Film Show. Royal Hotel, Bristol. 7.30 p.m.

**19th April**

**Institute of British Foundrymen, London Branch.** Annual General Meeting. Constitutional Club, Northumberland Avenue, London W.C.2. 7 p.m.

**20th April**

**Liverpool Metallurgical Society.** "Continuous Casting of Aluminium Alloys," by W. M. DOYLE. Followed by the thirteenth Annual General Meeting. Department of Metallurgy of the University of Liverpool. 7 p.m.

**21st April**

**West of England Metallurgical Society.** "Temperature Measurement," by J. A. HALL. The College of Technology, Ashley Down, Bristol 7. 7.30 p.m.

**26th April**

**Institute of British Foundrymen, London Branch (Southampton Section).** (Joint Meeting with the **Southampton Metallurgical Society**). Annual General Meeting followed by "Development of Cast Metals," by H. T. ANGUS. Technical College, St. Mary's Street, Southampton. 7.30 p.m.

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DAVY AND UNITED ENGINEERING CO., LTD., a member of the Davy-Ashmore group, has secured a contract to build a 32 in. and 57 in. × 98 in. 4-high reversing hot breaking down and plate finishing mill for the works at Chippis, in Switzerland, of A.I.A.G., Aluminium-Industrie-Aktien-Gesellschaft. The new mill will be capable of producing aluminium plate up to 90 in. wide and down to $\frac{1}{4}$ in. minimum thickness. The value of this contract exceeds £500,000.

# Aluminium and its Alloys in 1960

## Some Aspects of Research and Technical Progress

By E. Elliott, A.Met., F.I.M.

*Chief Metallurgist, The Aluminium Development Association*

*Attention is drawn to work published in this country and the U.S.A., reporting research and technical progress in the various aspects of the metallurgy of aluminium and its alloys, including extraction, founding, fabrication, constitution, properties and standardisation. Reference is also made to interesting applications of these materials.*

(*Continued from page 70 of the February issue*)

### Joining

It is probably a sign of some maturity in the techniques of joining aluminium and its alloys that fewer articles seem to be appearing on the subject than was the case a few years ago. Eldridge[89] has brought us up-to-date with fusion welding, resistance welding, ultrasonic welding, brazing and soldering, with some reference to other joining methods such as riveting and adhesive bonding. He notes that some of the advances of recent years are now being embodied in new British Standards. Short-arc welding, with low currents and fine wires, operates according to McElrath[90] by transfer of material during shorting of the wire to the work. This occurs at a rate of from 20 to 200 times per second. The process extends downwards the thickness of material that may be welded, and to that extent tends to replace the tungsten-arc method. Delong, Bradbury and Reid[9] have heated the wire used in MIG welding of aluminium alloys by passing it through an insulating sleeve. They find that this results in a decrease in necessary welding current, or, alternatively, an increased deposition rate with the same current, and control of operating conditions is more exact, so that possibly thin gauge materials might be successfully welded at high rates of deposition.

Some excellent coloured stills of transfer of aluminium in inert gas metal arc welding are given by Needham, Cooksey and Milner;[92] they are from sequences photographed at 9,000 frames per second. The authors conclude that high-velocity plasma jets pull away globules from the electrode wire, and they have shown good agreement between their film records and theoretical predictions of behaviour applying fluid-flow principles.

Joining wrought to cast aluminium alloys is regularly practised, but for ballistic missile applications it is obvious that satisfactory strength and ductility in the joint are vital. Orysh and Betz[93] joined aluminium-magnesium, aluminium-magnesium-zinc, aluminium-silicon-magnesium, aluminium-copper and aluminium-silicon casting alloys to sheet in aluminium–4% magnesium alloy by tungsten-arc welding; as might have been expected, combinations giving $Mg_2Si$ in the weld were the least satisfactory, while the aluminium-magnesium-zinc alloy gave gross porosity. Aluminium-magnesium and aluminium-copper casting alloys were attached satisfactorily using aluminium–5% magnesium filler wire. The properties of MIG welded aluminium-magnesium wrought alloys of various compositions have been determined by White[94] and his collaborators; they found that the toughness of a weldment depends upon the hardness difference between heat-affected zone and basis material, size of heat-affected zone, and relative magnesium content of fusion zone and basis material, filler metals of high magnesium content giving the highest toughness. Daley[95] has shown that in the MIG welding of aluminium-magnesium alloys, covering the range 2¼–5¼% of the alloying element, proper cleaning is as important as optimum welding conditions to obtain high weld efficiencies; cleanliness is next to godliness. An interesting series of curves shows that at high content of porosity, tensile strength suffers more than either proof stress or elongation. Also using MIG welding, Stern[96] and his collaborators compared the weld efficiencies of aluminium-magnesium work-hardened and aluminium-magnesium-silicon fully-heat-treated alloys; tensile strengths approaching those of the annealed materials were recorded. In large-scale low-cycle fatigue tests, the aluminium-magnesium alloys all gave about the same value of 6½ tons/sq. in., while the alloy similar to H20-WP was 1½ tons/sq. in. lower. Using similar alloys, Brungraber[97] has tested welded box beams in bending, with satisfactory results; after re-heat-treatment, the aluminium-magnesium-silicon alloy test pieces deflected only a quarter to half as much before fracture, although their strength was enhanced.

The argon-arc spot welding of aluminium was frequently mentioned in the literature some years ago, but met with little success in practice. Gourd and Copleston[98] show that this was due to the use of an A.C. power source; their improved and successful method employs D.C. with a current decay system, giving deep penetration and consistent spots. At present it has not been found possible to improve the appearance of welds by avoiding a depression on the top surface.

One important function of the metallurgist is to discover the causes of failures; for fractured welds he has been provided with a useful guide by Burch.[99] As is so often the case in papers of the nature of Burch's, the illustrated examples are quite frightening, but perform the function of instruction better than the longest verbal description. The way to avoid failures is by close inspection and testing of welds; Young[100] has described all the tests at present in use, listing them under visual and non-destructive on the one hand, and destructive on the other. He also distinguishes between tests for research, for procedure approval, for welder approval and for quality control.

Of the articles concerned with specific applications, the most detailed published recently is by Woodwood[101] on the fabrication of vessels for sub-zero use, particularly those made from thick plate. This excellent paper is full of detailed tabular matter giving full instructions on how to make welds; perhaps the table on choice of filler rod is too detailed, and those making a selection may find difficulty in deciding whether strength is more important to them than corrosion resistance, or perhaps economy and ease of welding beats both. Wilcox and Hubbard[102] have described the manufacture in aluminium-magnesium alloy of the world's largest rail hopper cars, principally by automatic MIG welding. The illustrations in this account are most informative and impressive, and give a clear indication of the size of the project and the almost production line techniques employed. Turning to a quite different type of vehicle, Hoetger and Moen[103] have described the application of mechanised welding to the manufacture of an aluminium alloy rocket engine using liquid fuel. Over 1,600 ft. of pipe[104] of diameter 4–14 in. have been welded together by MIG and TIG methods, in an alloy similar to HV20-WP, and will convey daily 50 million cubic feet of natural gas. No doubt a flexible backing bar would have been of use in this work; Jenkins[105] has described such a bar made from curved frames in high strength aluminium alloy and stainless steel grooved segments.

Ultrasonic welding is still at the stage where much work is needed before it is fully understood. Weare, Antonevich and Monroe[106] have investigated the mechanism of bonding and the effect of material; their tests seem to indicate that joining is due to the formation of a thin molten film at the interface, although solid state bonding is not altogether ruled out. Removal of the oxide film before welding does not improve joint strengths in aluminium. According to Noltingk,[107] aluminium is the most easily welded of metals by ultrasonic means; he shows by using colour anodised material that the oxide film is broken up and reorientated and contact of bare metal secured to give an effective bond. In considering applications, reference is made to the possibilities of joining thin foil. Potthoff[108] and his friends have used ultrasonic welding to join dissimilar metals difficult to bond by other means, including combinations of aluminium with copper and with silicon for electrical applications.

Precision electronic spot welding[109] may be employed for joining aluminium foil, and has been used in making honeycomb structures for aircraft. Johnstone[110] and his co-workers have related experience with high frequency resistance welding in tube manufacture; several metals have been used, including aluminium and aluminium-magnesium alloy.

In an investigation of bond strengths in cold pressure welds, Vaidyanath and Milner[111] found that scratch brushed surfaces gave the best results on aluminium, due to effective removal of surface contaminants and to the formation of rough hard layers which adhere under pressure and then break up, exposing the maximum area of completely clean metal for bonding. Anodic coatings also gave good bonds, after heating at 500° C.

Woods[112] has used a propane-air flame to braze aluminium–2¼% magnesium alloy. This flame, being lower in temperature than that of oxy-acetylene, causes less formation of magnesium oxide, and the lower heat input facilitates wetting with the brazing alloy so that, especially for the less skilled operator, it has advantages.

## Constitution

Giants in the land are always spoken of in the past tense. Steele and Collins[113] had to face them very much in the present as intermetallic constituents in high strength aircraft alloys; they were up to 0·1 in. long, and consisted of primary crystals of $CrAl_7$ with the chromium partly replaced by other transition elements. By establishing a formula for the phase boundary between primary aluminium and primary $CrAl_7$ in Al-Zn-Mg-Cu alloys containing Cr, Mn, Fe and Ti, these authors set maximum limits on these four elements, and so slew the giants, who were never again encountered in production materials.

## Properties

It has been fashionable for some time to accept that aluminium alloys can have no part in the aeroplanes of the fairly near future, because of kinetic heating. As Doyle[114] points out, however, the skill and experience acquired by the aircraft and aluminium industries in building aluminium alloy aircraft should not be lightly discarded; neither should problems in heating up of non-metallic aircraft parts be glossed over. Doyle goes on to present the known data about aircraft aluminium alloys at mildly elevated temperatures, and concludes that much work remains to be done, especially to provide methods of extrapolation from present knowledge. Materials for rockets must undergo even more arduous conditions, and Jones[115] sees the development of suitable alloys of aluminium and other metals as the great modern challenge to metallurgists. He gives aluminium few tasks in the most advanced missiles, but notes its successful use in the first stage structure of existing rockets. Krupka and Taylor[116] have used the plasma discharge arc to simulate the heating involved when a space vehicle re-enters the earth's atmosphere, and compared its effects on a number of materials. They find that certain plastics seem to offer the best resistance to wearing away or ablation by the effect of the heat; under these conditions aluminium has an effective heat of ablation (in BTU/lb.) higher than has stainless steel.

One of the aluminium alloys developed to offer good strength properties at mildly elevated temperatures is that known in the U.S.A. as X2020, which has a nominal composition of 4·5% Cu, 0·5% Mn, 1·1% Li, and 0·2% Cd; Spuhler[117] and his colleagues have summarised its properties at temperatures up to 700° F. This lithium-bearing alloy, after 30 minutes at 400° F., still has about 70% of its room temperature strength; its known tendency to notch sensitivity demands good design to eliminate stress concentrations as far as possible. Attention has also been devoted to lithium in this country. Thus Jones and Das[118] have determined the tensile properties of aluminium-lithium binary alloys, and ternaries formed by additions of zinc, magnesium, tin or copper. None of these alloys offered very attractive properties, the binary ones giving only 9½ tons/sq. in. tensile strength and the best ternary 17 tons/sq. in. with 10 tons/sq. in. proof stress. Silcock[119] has studied the ageing of aluminium-copper-lithium alloys at 165° C. with and without an addition of 0·1% cadmium and of prior cold work. The work is confined to identification and modes of occurrence of the various types of precipitates.

*Courtesy of Alcan (U.K.), Ltd.*
**Aluminium has played an indispensable part in the development of the road-railer.**

A few years ago the word fatigue as applied to metals possessed a special fascination for quite a wide variety of people, from industrialists to reporters on the more sensational newspapers. The phenomenon has now receded in popularity, but research continues to elucidate its problems, both fundamentally and in the collection of data. Under the latter heading falls recent work by Doyle and How,[120] comparing the effect of notches on the fatigue resistance of two high strength aluminium alloys, of the Al-Cu-Mg and Al-Zn-Mg-Cu types. Both alloys were quenched in boiling water, and —perhaps surprisingly—the former material was shown to be the more notch-sensitive of the two at $2 \times 10^6$ cycles. Following a consideration of recent applications of mathematics to cumulative fatigue damage, Williams and Hughes[121] conclude that its assessment requires special test data and does not make use of ordinary S/N curves, while a significant factor is the cumulative variation in stress amplitude.

Much less is known about fatigue of welds in aluminium than that of unwelded material, and Tomlinson and Wood's[122] summary of available data is therefore to be welcomed. Some of the conclusions are not entirely encouraging; thus the shape of reinforcement of oxy-acetylene welds is considered the best, with MIG welds somewhat worse than TIG. The authors see promise in the improvement of fatigue resistance by readjustment or removal of unfavourable internal stress. Many metallurgical and engineering terms are particularly descriptive; fretting is one of them, as well as the name of its product—cocoa in England, blood in Germany. Teed[123] has reviewed the present knowledge of the phenomenon, so insiduous in reducing fatigue resistance, and concludes that far too little is known, partly due to metallurgical neglect and—even worse—research applied without sufficient attention to knowledge of chemical composition and metallurgical structure. Comparing the effects on subsequent precipitation behaviour of fatigue strain and unidirectional strain, Stubbington[124] has shown that fatigued aluminium–12·5% magnesium alloy softened rapidly during the early stages of ageing; if the fatigue stress was applied after solution treatment, subsequent precipitation was fine instead of in a Widmanstätten pattern. Similarly, fatigue between solution and precipitation treatment of an Al-Zn-Mg-Cu high strength alloy also caused refinement of the precipitate.

The names of Paillard, Wilm and Moore are associated with the origins of precipitation hardening, the last two in connection with aluminium alloys. Mudge,[125] following a tour of Europe, has written a very brief history of the early years of this metallurgical process, and concludes by saying that "the matter is still only beginning." Working with high porosity aluminium-zinc alloys in sheet form, Garwood and Davies[126] put forward the hypothesis that a large concentration of vacant sites is retained in the lattice on quenching; restricted hardening in uncrystallised grains is considered to be due to rapid elimination of excess vacancies in the substructure. In a further paper these authors, with Richards,[127] describe a face-centered-cubic transition phase detected by X-ray diffraction during isothermal transformation at 200° C. of an aluminium–25% zinc alloy; this precipitate contained 80% zinc, and was followed by a plate-like hexagonal precipitate.

Following an early announcement in *Nature*,[128] Polmear[129] has given a detailed account of his experiments on the effect of copper and silver on the ageing mechanism in aluminium-zinc-magnesium alloys. The most interesting finding is that small silver additions to Al-Zn-Mg-Cu alloys of compositions similar to those used in aircraft construction raise the precipitation temperature at which maximum hardness may be obtained, thus possibly allowing stress-relieving to accompany precipitation treatment. Further, electron micrographs show that, with silver additions, the precipitate is finer and more evenly distributed in grain boundary regions. Taken together, these findings hold out hope that silver additions and suitable heat treatments might have an important beneficial effect on stress corrosion resistance.

Saulnier and Miraud,[130] using slices of metal a few Angstroms thick, prepared by electrolytic polishing, have applied the electron microscope to produce electron diffraction patterns. They study the sub-grain structure in aluminium-magnesium alloy, precipitates in aluminium-copper alloy, and the compound $Al_2Mg_2$ in aluminium-magnesium alloy, as well as other non-ferrous and

ferrous metals. Two articles have appeared by Bichsel on electron microscopy ; one is concerned with an investigation of sub-grain structure in high purity aluminium,[131] while the other is general,[132] describing the application of oxide replica techniques and the examination of thin foils. The illustrations in all these papers are impressive scientifically and attractive aesthetically ; it is only a matter of time before they receive the attention of designers of wallpaper, floor coverings and similar goods.

Single crystals continue to attract the experimenter ; McKinnon[133] has studied the work-hardening of a super-purity aluminium crystal, and indicated that during stage I, that is the period of slip on (111) plane of maximum resolved shear stress, the rate of hardening is determined by the amount and type of uniformly distributed secondary slip. Greetham and Honeycombe[134] have deformed single crystals of aluminium–4·5% copper given various ageing treatments after solution treatment. Under-aged crystals showed a marked yield point followed by a period of low hardening, while over-aged crystals and those treated at the optimum temperature, though showing no yield point, strain-hardened rapidly. By X-ray and metallographic study, Richards and Pugh[135] have determined the sequences of behaviour of super-purity aluminium during rolling and annealing. Structures after various amounts of cold reduction are illustrated as photomicrographs and X-ray transmission patterns.

Blade, Clare and Lamb[136] have used levitation melting to provide ingots of zone-refined aluminium containing additions of various elements, which were then rolled to sheet for determination of recrystallisation temperatures. As little as 0·001 at.% of the addition elements was sufficient to produce most of the retardation of recrystallisation ; silicon, copper and magnesium each caused an increase of recrystallisation temperature of 50–100° C., while for iron, chromium and manganese a figure of *c.* 200° C. is quoted. At temperatures varying from 195–500° C., Ormerod and Tegart[137] have subjected super-purity aluminium to torsion stresses, and determined torque values which are converted to shear stress, while specimen revolutions are converted to shear strain, the two being used to draw true stress/strain curves. Davies[138] has performed stress-rupture tests on the aluminium–1% nickel alloy favoured for resistance to corrosion by high temperature water, and obtained 1,000 hour values of 0·75 at 350° C., 1·8 at 250° C., and 4·2 at 100° C., the units being kg/sq. mm. ; English eyes would have preferred tons/sq. in.

## Corrosion and Protection

No form of degeneration of metals is more insidious than corrosion, and the volume of work published on the subject is a measure of the seriousness with which it is viewed. Evans[139] has produced a monumental volume of great authority on the corrosion and oxidation of metals in general, with an author index containing no less than 3,000 names. A fat volume, but the scribbling has been very well worth while, and as with Gibbon's work it will well outlive the author. Another useful book is that written by Rogers,[140] principally for the education of naval constructors who are responsible for the maintenance of ships of war ; aluminium receives its due meed of attention, with alarming illustrations of what happens when wrong procedures are adopted, and details of correct design and practice.

The power of the corrosive enemy must be recognised and assessed ; Great Britain has the unenviable reputation of being a particularly aggressive place. Ambler[141] has found that the distribution of chloride in the British atmosphere has the same general relation to distance from the sea as in West Africa, and that the corrosion of steel and zinc bears no relation to salinity ; encouragingly, he considers that the corrosion of his aluminium specimens was so small as to give high errors on cleaning. A new hazard has been added to corrosion testing. At Llanrhystyd, Ambler's specimens were liable to be licked by cows on the landward side ; he states that this would not be expected to give low results, but this surely depends on the corrosivity of cow saliva as against the beneficial effects of regular cleaning.

In continuing its work on the basic causes and mechanism of corrosion, the National Bureau of Standards[142] in the U.S.A. has established that with large single crystals of high purity aluminium exposed to an acid mixture, configuration of etch pits differed according to crystallographic orientation, and the rates of attack varied radically from those observed in an alkali mixture. Edeleanu[143] has studied the pitting mechanism, using 99·999% aluminium foil in sodium chloride solution, and demonstrated that the rate of attack per unit of active area inside a pit is a constant, and that changes in an external polarising current change the rate of pitting only by altering the active area. An electron micrograph of a pitting system illustrates effectively the frequent changes in direction of the attack. In a general summary of the causes of pitting and its effects, Robinson[144] makes the cardinal point that to avoid it one must eliminate the chloride ion or inhibit it ; it is not always possible to adopt either of these admirable actions, so that pitting must sometimes be lived with and allowed for in design and selection of materials.

Susceptibility to intercrystalline corrosion may be a less serious matter than proneness to stress-corrosion ; indeed, in the high strength Al-Zn-Mg-Cu alloys, stress-corrosion failure can occur when very little evidence of corrosive attack is to be detected. In developing tests for the susceptibility of this type of alloy to intercrystalline attack, Ketcham and Taylor[145] do not mention stress-corrosion, and while their tests are no doubt of value, tests including stress application would be preferred. Silver is highly cathodic to aluminium, and alloys containing large additions of silver might be expected to be correspondingly low in corrosion resistance. This has been shown to be the case by Stadelmeier and Whitener[146] ; in their aluminium-silver alloy, $Ag_2Al$ was precipitated on the grain boundaries, and in a refrigerator atmosphere samples were completely pulverised in four weeks. A Committee of the National Association of Corrosion Engineers[147] has reported on its investigations of techniques applicable to the examination of aluminium corrosion products, including X-ray diffraction and fluorescence, thermal analysis, electrographic methods, spectrographic analysis, microscopic examination and quantitive and qualitative tests.

Having purified water sufficiently for it to merit the application high-purity, the user is anxious to keep it so, and Knoedler and Gordon[148] have assembled test data on many materials that may be used for containers, pipes, etc., including steel sprayed with aluminium, and the same combination coated with a polyvinyl top coat. Commercially pure aluminium and aluminium-man-

**A general view of some of the aluminium rail vehicles on show at the Strasbourg Exhibition, 1960.**

ganese alloy tanks were also used, and the water showed 0·035 parts per million of aluminium after 56 days' storage ; a very low proportion. In comparing metals for compatibility with 90% hydrogen peroxide, Bloom[149] and his co-workers award classification 1 only to pure aluminium, certain aluminium alloys and zirconium. A rocket fuel rejoicing in the name of unsymmetrical dimethylhydrazine has been successfully stored in aluminium containers for three years without ill effect, as reported by Raleigh and Derr.[150] Many somewhat unusual chemicals are needed in conjunction with rocket engines, and Geiger, Schuler and Mowers[151] have discussed material selection problems in the light of present knowledge. Aluminium is compatible with hydrogen peroxide, nitrogen tetroxide, liquid fluorine and inhibited red fuming nitric acid, amongst other rocket chemicals.

Aylmore, Gregg and Jepson[152] have studied the oxides formed when aluminium is heated in dry oxygen and interpreted their results as showing crystallisation of an initially formed amorphous layer. Using an A.C. bridge, Lorking[153] measured the capacity and thus the thickness of non-porous oxide films on aluminium ; chloride ions in solution increased the permeability of the film, and this was detected by potential measurements. Since a general air of pessimism permeates the account by Capp and Philibert[154] about ship corrosion, their remarks about trouble with aluminium are perhaps less unacceptable ; however, they seem to be ill-informed about developments since the war in such matters as riveting and boundary bar joints, and the general avoidance of bimetallic corrosion. The stupid things that are still done are exemplified in an account by Brooks[155] of a floodlight from a fishing vessel, that had castings in an aluminium alloy containing 2½% copper, was bolted together with brass bolts, and employed an absorbent fibre gasket. It seems hardly conceivable, but these things still happen, even in the second half of the twentieth century. In the aircraft industry, hazards are much more fully recognised ; Heath[156] has shown how modern aircraft design is being modified to provide access to all parts for inspection, to ensure that unobserved corrosion cannot proceed to cause a catastrophe. This requirement in design is, of course, most important in modern aircraft from which long service lives are expected.

Corrosion at welds has not proved a serious problem with aluminium since the dangers of flux entrapment were eliminated by the adoption of inert gas-shielded welding methods ; however, trouble with large gas-welded cooking pans in aluminium–2% magnesium alloy described by Latimer[157] was not due to flux residues. " Knife-edge " attack along the sides of the welds was shown to be associated with the coarse structure of the partially fused zone, and the presence of continuous $\beta$-phase on the grain boundaries of the heat-affected zones. This could be avoided by welding at a faster rate with less heat input, e.g. by tungsten-arc welding. Oldfield and Twigg,[158] investigating the staining of stainless steel tableware, tested blades in contact with galvanised iron and with aluminium in Sheffield tap water at 60° and 100° C. They concluded that aluminium containers are reasonably safe for trays or baskets for washing stainless steel cutlery, but galvanised iron can cause staining. Aluminium-magnesium-silicon alloy (similar to H9-P) pipe, TIG welded, and used for sour gas was inspected by Flournoy[159] after being buried for six years without protection in a soil of sandy loam and broken caliche. Where failure had occurred, it was by pitting from the outside, and chlorides were detected in the corrosion product. This experience shows that aluminium is resistant to sour gas, and may be installed bare underground if protection is afforded at local spots of high corrosivity.

If one keeps the anti-freeze in the cooling system of one's car from year to year, one runs the risk of corrosion of the cast-iron parts of the circuit, due to increase in acid content and reduction of inhibitor content of the cooling liquid. This has been shown by Collins and Higgins,[160] who also state that the danger of corrosion of other metals by the deteriorated anti-freeze is slight ; only occasionally has slight pitting been seen with aluminium, and no corrosion necessitating replacement has resulted. Investigating the special case of hypereutectic aluminium-silicon alloys under conditions related to car engine cooling systems, Craig and Woods[161] have shown

that such alloys, even when coupled to copper, are corroded to a negligible extent if there are suitable inhibitors in the coolant; in general, hypereutectic aluminium-silicon alloys are more corrosion resistant than cast iron.

Sundararajan and Char, continuing their studies of inhibition of the corrosion of aluminium, have assessed the effects of acridine, nicotinic acid, dextrin, thiourea and tannic acid in dilute hydrochloric acid;[162] all were efficient. In a second paper[163] these authors describe polarisation studies in acid and alkaline solutions, with thiourea and dextrin as inhibitors, and conclude that cathodic protection is possible in acid solutions in the potential range $-0{\cdot}55$ to $-0{\cdot}80$ V. In both these papers one meets again the curious material previously described by Sundararajan and Char, namely 92% pure aluminium, containing 3% Fe, 4% Mn, 1% Si; doubts about decimal points return more strongly than ever. Using some impressive mathematics, Bauer and Eddy[164] have compared various possible anode materials for the protection of water tanks. One interesting factor affecting choice is whether or not the water freezes and breaks the anode or suspension; if it does, aluminium is used, because of its cheapness.

Chemical conversion coatings have been summarised by Ayres,[165] considering them principally from the point of view of corrosion resistance, which is conferred by low chemical activity and solubility. Wells[166] and Pinner[167] have surveyed recent advances in chemical and electrolytic polishing, on all relevant metals including aluminium. Blencowe and Brace[168] have made a pilot plant study of the Aluflex process, which uses a sulphuric acid electrolyte, with small additions of chromic acid, for electro-brightening. A good standard of brightness was attained.

The automatic control of anodising[169] is one method of cutting costs, and a window manufacturer has installed such a plant for treating aluminium window frames. This is the first plant in this country to be so equipped, the advantages being that skilled labour is not required, the anodic film is constant, and the human factor is eliminated. Over 2,000 tons a year of aluminium strip are used for can manufacture in Norway; Nickelsen[170] has described the continuous anodising and lacquer sealing of this material. Future plans envisage a four-fold expansion of output, and additional uses of the product, such as crown corks, pharmaceutical containers and architectural applications. In considering the possibilities of a large range of aluminium alloys for bright anodising, Howitt and Jenks[171] emphasise the importance for good finish of correct metallurgical composition and structure. They note that for bright finishes on high strength components Al-Mg-Si and Al-Zn-Mg-Cu alloys offer promise, if produced under rigidly controlled conditions.

A translation has appeared of a well-known German book[172] on anodising, which is particularly useful for its descriptions of the plant and equipment used in that country.

Plating of aluminium, although well established, is not applied to any great extent; it is therefore interesting to read of the application of chemical nickel[173] to aluminium to provide wear resistance and solderability. Hammond and Williams[174] have reviewed the available information on the effect of electroplating on resistance to fatigue. They note that chromium coatings on aluminium alloy cause appreciable reduction in fatigue strength.

Vitreous enamelling of aluminium is getting around again, and Lister and Brace[175] have described the present position in this country. The article covers pretreatment, slip preparation, processing and quality tests, as well as some current applications. One recent use of vitreous-enamelled aluminium is in architectural trim for a college[176] in the South of England. Plastics coatings[177] are applied to aluminium and its alloys for several reasons, notably electrical insulation, low friction characteristics, reduction of impact damage, and to eliminate dangers of bimetallic corrosion; the relative merits of a range of such coatings have been discussed.

Clark[178] has provided an addendum to his previous work on the protection by painting of aluminium alloys for use in chemical factories; painted HS30-WP was still in good condition after seven years' exposure, and much painted sheet has been installed in aggressive areas. Failures of aluminium alloy hook bolts occurred when they became coated with caked damp potassium chloride. It is good to read of the repainting of aluminium prefabricated bungalows;[179] so many of them received no such treatment following their installation in the period 1945–1947. The case described was the first repainting in 15 years, and was accomplished with a plastic emulsion paint in several colours. Pressure die-castings forming an outboard motor[180] are pre-treated by Bonderizing, receive a stoved priming coat and finally a special modified epoxy-resin finishing coat. In Weatherometer tests, the finish was unaffected by eight weeks' exposure.

The literature on the protection of iron and steel by aluminium coatings continues to increase, and Andrews[181] has reviewed the various methods of application and the properties of the coatings produced. Payne[182] and Curson[183] have discussed metal spraying generally, and both take the view that, while aluminium is the best coating for steel in industrial exposure, it is slightly inferior to zinc in marine environments; this latter distinction is not accepted by all observers. Nicholls[184,185] provides two papers on hot-dipping, one concerned with all coating metals and the other with aluminium only, covering both batch and continuous aluminising. Using metal spraying and hot-dipping followed by a diffusion treatment, Mitchell[186] and his colleagues have shown that aluminising improves the resistance of plain carbon and low alloy steels to creep and fatigue at 650° C., but it must be ensured that any reduction of strength due to hot-dipping is more than compensated by increased resistance to scaling.

Porter[187] has joined the ranks of those who regularly submit to the slavery of trying to give some impression of the literature appearing during the year by providing an informative survey of that on the corrosion and protection of aluminium and its alloys.

## Applications

Following the interest created by the *Oriana*, the launching of the *Canberra*, designed for the run across the Pacific to North America, has confirmed the acceptance by shipbuilders of aluminium superstructures. Brierly[188] has described the design of the ship, and presented some thoughts on the extent to which the superstructure contributes to the strength of the vessel. Two French alumina ships,[189] bearing the appropriate names *Sainte*

*Claire Deville* and *Paul Héroult*, have deck structures of aluminium ; approximately 100 tons of the metal were used in each. An oil tanker[190] for the Rhine, aptly called *Aluminia*, is of all-aluminium construction, and so has a considerable increase in capacity for the same draught as a comparable steel vessel. In order to obtain maximum lightness, a landing craft[191] for the Air Ministry has been constructed in aluminium ; it provides an effective vehicle deck length of 30 ft. The credit for building the world's first nuclear ship has gone to the Russians, but the Americans are to have the first nuclear aircraft carrier[192] and it has been announced that the ship will have aluminium elevators.

Aluminium hatch covers[193] are now well established, fabricated by welding or casting. Complete ship sets of the welded type have been installed in three Royal Mail Line vessels, the method of construction being approved by Lloyd's Register of Shipping. Elliott[194] has described the history and testing of aluminium alloy side scuttles for ships, which are accepted by the Ministry of Transport. Stands for marine compressors[195] are made as gravity die castings in alloy LM6-M ; apart from lightness and corrosion resistance, the choice of aluminium is dictated by magnetic considerations. In testing forged aluminium ships' fenders[196] which in use are fitted with rubber tyres, two ships totalling 52,000 tons came together at an angle of 15°, one ship stopped and the other doing 2½ knots, without damage or serious jarring.

A useful table has been published indicating the applications of aluminium[197] in the 1961 models of various motor cars, together with a brief forecast of what may happen further ahead. One possibility, of course, is the adoption for the average car of aluminium cylinder blocks and heads, and their merits and difficulties have been summarised.[198] Aluminium continues to be the standard material of construction for buses ; a new forward entrance design[199] with low floor has been described. So much is pre-packaged nowadays that one should not be surprised to learn that there is now available a kit of aluminium parts to make a lorry body.[200] A tipper for granite chippings[201] has an all-welded body in aluminium weighing only 12¼ cwt. with a payload of 16¼ tons. Bulk transport of powders by containers fitted for low pressure discharge continues to expand ; a sugar container[202] is made by welding from sheet in NS5 and NS6, and sections and tube in H9-WP. Underframe pedestals[203] for lorry bodies are gravity die cast in alloy LM4-M ; cast treads in aluminium alloy[204] form part of the " Trav-O-Lator " for the Bank station in the City.

The past year was an important one for aluminium in railway applications. The Aluminium Development Association, in conjunction with the Institution of Locomotive Engineers, held in May a successful symposium on the subject, the proceedings of which have now been published. Then, in June, the Centre Internationale de Developpement de l'Aluminium arranged at Strasbourg[205,206,207] an international exhibition of aluminium in railway rolling stock, at which no less than forty-five vehicles were on show. Early in the year the first aluminium trains[208] were delivered to the Piccadilly Line, following successful experience on the District Line.

The account has been published[209] of the A.D.A. Building Symposium held in 1959 ; its papers and discussions present in one volume a large part of present

*Courtesy of C. C. Wakefield, Ltd.*

**Aluminium curtain walling on Castrol House.**

knowledge on the subject of aluminium in building. Johnson's[210] exhaustive paper on curtain walling systems has been serialised separately. A new system of attachment[211] for corrugated aluminium sheeting for industrial building involves the impalement of inner sheeting and insulation material on a steel stud, followed by the outside sheeting and a steel cap. Wall cladding need not be made from sheet ; an attractive extruded cladding[212] in alloy HE9-P is available with a secret fixing device. The Palico building[213] in Manila has been provided with a curtain walling system by a British company, in anodised aluminium–5% silicon alloy, which gives an attractive natural grey colour. An Applications Brochure on aluminium corrugated and troughed sheeting[214] is now available, giving full details of sheet profiles, fixing arrangements, and installation practice, together with general information on the characteristics of aluminium important in roofing and vertical cladding.

After all the excitement, the aluminium eagle on the new U.S. Embassy building[215] turned out to be quite unobjectionable. Despite its size, it does not stand out when in place on the large building ; even its baldness is not at all obvious. This and other features in aluminium have been described, notably the gold anodised frieze and mullions. Standardisation has been applied to a large degree in the design and manufacture of aluminium prefabricated houses.[216]

Over the new headquarters of the American Society for Metals[217] in Novelty, Ohio (well named !), is a 250 ft. diameter geodesic dome, made from 13 miles of extruded aluminium tube and tension rods. A self-supporting roof[218] is made from braces of alloy HE30-WP with sheet of NS3, and has a loading of only 2½ lb./sq. ft. of area roofed. The aluminium roof of the Scottish Ski Club Hut[219] on Meall a' Bhuiridh was lifted in sections from the roadside at Moor of Rannoch by helicopter ; at last the engineer has the elusive skyhook at his

disposal. To prevent the hardening of a bitumen roof by the sun, it may be capped with aluminium foil[220] 0·015 mm. thick.

Aluminium windows are even better if double glazed, and a choice of types is offered by a Swiss design[221] now being produced in this country. Aluminium doors[222] are now available in standard sizes, either natural finish or anodised.

Towers in aluminium have the advantages of ease of transport and erection. One type[223] that is available is made from tubing in HV30-WP and castings in LM8-WP and is partly constructed by welding. Another larger design[224] is also in H30-WP, and is 366 ft. high. A welded tower,[225] made in the U.S.A. in an alloy similar to HE20-WP, is sufficiently strong to withstand winds of hurricane force. The new Roman Catholic Church at Merstham in Surrey has an aluminium steeple,[226] again in alloy H30-WP. To speed the building of bridges on the Oxford by-pass, the contractors are using an aluminium launching truss[227] to handle concrete beams of 78 ft. span and weighing 42 tons each. The advantages of aluminium for seaside railings[228] are obvious, and their extra initial cost is soon recovered because of the absence of maintenance charges. Installations have been made at various places in Kent.

It is unfortunate that economics ensure that news of progress in the use of aluminium in canning comes mainly from abroad. A brewer in the U.S.A. is producing his own beer cans[229] in aluminium by a continuous process including direct casting of strip and impact extrusion. A quick-opening aluminium can end[230] has welded to it a tag which, when pulled, tears away the whole of the top leaving a safe edge. Elliott[231] has described the manufacture and testing of aluminium collapsible tubes, which nowadays represent somewhere between 60% and 80% of the output of this type of container.

Aluminium is frequently used to encase insulation on pipelines. Recently a 30 in. steam main[232] together with smaller insulated pipes was afforded permanent protection by wrapping with aluminium strip fastened by "Pop" rivets; 7 tons of metal were needed. In Louisiana, a 6 in. diameter pipeline[233] for high pressure gas, one mile long has been installed by welding using butted tubes. Concrete pipe lines may be formed *in situ* by using aluminium formers[234] for the inner core, and the earth of the trench for the outer mould. In the brewing industry, aluminium is used in many ways, from the roofing of buildings to barrels; these applications have been described.[235]

An important advance in the electrical field is the development of shaped solid conductors[236] to replace the cores of stranded cable. Aluminium foil is being used increasingly for windings, especially in solenoids.[237] Thomas and Rata[238] have provided a comprehensive handbook on the design, construction and installation of aluminium busbars.

In the home and office, aluminium is welcomed for its lightness and pleasant appearance. Typewriter bodies[239] are made as pressure die-castings, and a description has appeared of one particular model. TIG welding is applied to the manufacture of aluminium chairs for both home and office use; an anodic finish ensures good appearance.[240] In a well-known gas cooker[241] with barbecue grill, pressure die-castings in aluminium are used for frame and burner parts.

In the headquarters of a famous oil company, an aluminium decorative mural[242] has been installed, measuring 50 ft. by 24 ft., and requiring no less than 3½ tons of metal. An account of the properties of super-purity aluminium[243] rightly stresses its decorative applications, since such beautiful finishes may be obtained upon it by brightening, anodising and dyeing.

## Standards

A most important event occurred in 1960—the publication of the first recommendation by the International Standards Organisation[244] dealing with aluminium (although it has the date 1959 it was not issued until the year of the gamekeeper). The document, R115, which covers pure aluminium other than refined aluminium in the form of remelt ingot and pigs, embraces five grades, namely 99·00, 99·30, 99·50, 99·70 and 99·80. It is not an international standard; its effect is indirect, in that each member country of the I.S.O. is morally bound, when writing or amending national standards on this subject, to make them not less stringent than R115. Also in the international field, the International Electrotechnical Commission[245] has issued its publication 121 on commercial annealed aluminium electrical conductor wire, which covers resistivity and mechanical properties. The document and some of its predecessors dealing with resistivity have been compared and discussed.[246]

Turning to British Standards, the B.S.I. has published a number of new and revised documents that mention aluminium. Aluminium-magnesium-silicon alloy overhead conductors[247] are the subject of B.S. 3242; the specified electrical and mechanical properties are in general in conformity with I.E.C. recommendations. Part 2 of B.S. 2901 covers wires in several metals for use as filler materials[248] in MIG welding, including all the standard purities of aluminium, an aluminium-silicon alloy and two aluminium-magnesium alloys. Two revised standards have been published for equipment for the fire service, and both include suitable aluminium alloys; B.S. 336[249] is for fire hose couplings, and B.S. 3251[250] for hydrant plates. Yet another revised standard is B.S. 2698[251] on containers and notes for filmstrips, aluminium being one of the permitted materials for containers.

At the request of the Local Authorities Standards Advisory Committee the B.S.I. has prepared and published B.S. 3272[252] which deals with aluminium food storgage bins, principally for school catering. In B.S. 3277[253] aluminium is one of the materials permitted in the manufacture of orthopædic thigh corsets and cuff tops.

An important standard was issued towards the end of the year covering tubular heat exchangers for general purposes, namely B.S. 3274.[254] In addition to other metals this covers suitable grades of pure aluminium and aluminium alloys and design stresses are given for various temperatures of operation.


REFERENCES

The Aluminium Development Association maintains extensive library facilities, and is prepared to lend its accessions for short periods to bona-fide enquirers in this country.

89 Eldridge, G. W., "Recent Advances in Joining Aluminium," *Metallurgia*, 1960, **61**, 55–60.
90 McElrath, T., "Short-Arc Consumable-Electrode Welding Applications and New Developments," *Welding Journal*, 1960, **39**, 1044–1050.
91 DeLong, W. T., Bradbury, J. H., and Reid, H. F., "Preheated Welding Wires and Their Effect on Welding Characteristics," *ibid.*, 328–333.
92 Needham, J. C., Cooksey, C. J., and Milner, D. R., "Metal Transfer in Inert-Gas Shielded-Arc Welding," *British Welding Journal*, 1960, **7**, 101–114.
93 Oryshi, M. S., and Betz, I. G., "Weldability of Aluminum Casting Alloys with 5086 Wrought Aluminum Alloy," *Welding Journal*, 1960, **39**, 342S–351S.
94 White, S. S., Manchester, R. E., Moffatt, W. G., and Adams, C. M., "Plastic Properties of Aluminium-Magnesium Weldments," *ibid.*, 198–198.

95 Daley, D. M., "Techniques for Welding Al-Mg Alloys," *ibid.*, 3018–3058.
96 Stern, I. L., Cordiano, H. V., and Digiglio, V. A., "Comparative Properties of Aluminum Alloy Weldments," *ibid.*, 4248–4328.
97 Brungraber, R. J., "Strength of Welded Aluminum-Alloy Box Beams," *ibid.*, 4178–4238.
98 Gourd, L. M., and Copleston, F. W., "Argon-Arc Spot Welding of Commercial Purity Aluminium," *Welding and Met. Fab.*, 1960, **28**, 368–374.
99 Burch, W. L., "How to Interpret Fractures in Aluminum Weld Metal," *Welding Journal*, 1960, **39**, 322–327.
100 Young, J. G., "Inspection and Testing of Aluminium Welds," *Light Metals*, 1960, **23**, 248–252.
101 Woodward, A. R., "Aspects of the Fabrication of Aluminium Vessels," *Welding and Met. Fab.*, 1960, **28**, 235–245.
102 Wilcox, D. V., and Hubbard, R., "Assembly-Line Fabrication of All-Welded Aluminum Covered-Hopper Cars," *Welding Journal*, 1960, **39**, 783–790.
103 Hoetger, R. L., and Moen, W. B., "Liquid Rocket Engine," *ibid.*, 1028–1036.
104 Anon., "Gas-Shielded Arc Welding Aids Fabrication of Aluminum Pipe Line," *ibid.*, 356.
105 Jenkins, C. M., "Expanding Bracelet Backing Bar Simplifies Welding of Missile Shells," *ibid.*, 1058–1059.
106 Weare, N. E., Antonevich, J. N., and Monroe, R. E., "Fundamental Studies of Ultrasonic Welding," *ibid.*, 3318–3418.
107 Noltingk, B. E., "Ultrasonic Welding," *Welding and Met. Fab.*, 1960, **28**, 260–266.
108 Potthoff, W. C., Thomas, J. G., and Meyer, F. R., "Ultrasonic Welding of Dissimilar-Metal Combinations," *Welding Journal*, 1960, **39**, 131–138.
109 Anon., "Welding Ultra-Thin Metal Parts," *Light Metals*, 1960, **23**, 106.
110 Johnstone, L. A., Trotter, F. J., and a'Brassard, H. F., "Performance Record of the Thermatool High Frequency Resistance Welding Process," *British Welding Journal*, 1960, **7**, 238–349.
111 Vaidyanath, L. R., and Milner, D. R., "Significance of Surface Preparation in Cold Pressure Welding," *ibid.*, 1–6.
112 Woods, P. F., "A Note on the Brazing of Aluminium and its Alloys with Air/Propane," *ibid.*, 489–490.
113 Steele, L. E., and Collins, D. L. W., "'Giant' Chromium Intermetallics in Commercial Al-Zn-Mg-Cu Alloys," *J. Inst. Metals*, 1960, **88**, 260–265.
114 Doyle, W. M., "Structural Aluminium Alloys for High Speed Flight," *J. Roy. Aero. Soc.*, 1960, **64**, 535–548.
115 Jones, E. S., "Rocket Materials—A Challenge for Metallurgists," *Journal of Metals*, 1960, **12**, 449–454.
116 Krupka, R. M., and Taylor, D. E., "Ablation Behaviour of Materials Subjected to Missile Re-entry Heat Flux Rates," *Corrosion*, **16**, 385t–389t.
117 Spuhler, E. H., Knoll, A. M., and Kaufman, J. G., "Lithium in Aluminum–X2020," *Metal Progress*, 1960, **77** (6), 80–82.
118 Jones, W. R. D., and Das, P. P., "The Mechanical Properties of Aluminium–Lithium Alloys," *J. Inst. Metals*, 1960, **88**, 435–443.
119 Silcock, J. M., "The Structural Ageing Characteristics of Aluminium-Copper-Lithium Alloys," *ibid.*, 357–364.
120 Doyle, W. M., and How, I. M., "Notch Fatigue Properties of Some High-Strength Aluminium Alloys," *Engineering Materials and Design*, 1960, **3**, 538–542.
121 Williams, T. R. G., and Hughes, D. H., "The Problem of Cumulative Fatigue Damage in Sheet," *Sheet Metal Industries*, 1960, **37**, 653–659.
122 Tomlinson, J. E., and Wood, J. L., "Factors Influencing the Fatigue Behaviour of Welded Aluminium," *British Welding Journal*, 1960, **7**, 250–264.
123 Teed, P. L., "Fretting," *Metallurgical Reviews*, 1960, **5**, 267–295.
124 Stubbington, C. A., "The Effect of Fatigue Deformation on the Dispersion of Subsequent Precipitation in Aluminium Alloys," *J. Inst. Metals*, 1960, **88**, 227–231.
125 Mudge, W. A., "The Earliest Days of Precipitation Hardening," *Metal Progress*, 1960, **77** (4), 79–82.
126 Garwood, R. D., and Davies, A. L., "The Effect of Structural Imperfections on the Age-Hardening of Aluminium-Zinc Alloys," *J. Inst. Metals*, 1960, **88**, 311–317.
127 Garwood, R. D., Davies, A. L., and Richards, G. L., "A Transition Phase in the Ageing of Aluminium-Zinc Alloys," *ibid.*, 375–378.
128 Polmear, I. J., "A Trace Element Effect in Alloys Based on the Aluminium-Zinc-Magnesium System," *Nature*, 1960, **186**, 303–304.
129 Polmear, I. J., "The Ageing Characteristics of Complex Al-Zn-Mg Alloys: Distinctive Effects of Copper and Silver on the Ageing Mechanism," *J. Inst. Metals*, 1960, **89**, 51–59.
130 Saulnier, A., and Miraud, P., "Application of Electron Microscopy," *Metal Treatment*, 1960, **27**, 91–100, 102.
131 Bichsel, H., "Application of Electron Microscopy," *ibid.*, 319–326.
132 Bichsel, H., "The Electron Microscope: Some Applications to the Study of Aluminium," *ibid.*, 409–414.
133 McKinnon, N. A., "First Stage of Work Hardening in Aluminium Single Crystals," *Nature*, 1960, **186**, 148–149.
134 Honeycombe, R. W. K., and Greetham, G., "The Deformation of Single Crystals of Aluminium–4·5% Copper Alloy," *J. Inst. Metals*, 1960, **89**, 13–21.
135 Richards, T. L., and Pugh, S. F., "Structural Changes in 99·990% Pure Aluminium During Rolling and Annealing," *ibid.*, **88**, 399–435.
136 Blade, J. C., Clare, J. W. H., and Lamb, H. J., "The Recrystallisation Characteristics of Dilute Aluminium Solid Solutions Prepared from Zone-Refined Aluminium by Levitation Melting," *ibid.*, 365.
137 Ormerod, H., and Tegart, W. J. M., "Resistance to Deformation of Super Pure Aluminium at High Temperatures and Strain Rates: Determination from High-Temperature Torsion Data," *ibid.*, **89**, 94–96.
138 Davies, V. L., "Stress-Rupture Testing of Aluminium-1% Nickel-0·5% Iron Alloy," *ibid.*, 22–23.
139 Evans, U. R., "The Corrosion and Oxidation of Metals," Edward Arnold, 1960, pp. 1094.
140 Rogers, T. H., "Marine Corrosion Handbook," McGraw-Hill Book Company, 1960, pp. 297.
141 Ambler, H. R., "Atmospheric Salinity and Metal Corrosion at Various Places in Great Britain," *J. Applied Chemistry*, 1960, **10**, 213–225.
142 Anon., "Basic Research in America," *Corrosion Technology*, 1960, **7**, 12–14, 20.
143 Edelenau, C., "The Propagation of Corrosion Pits in Metals," *J. Inst. Metals*, 1960, **89**, 90–93.
144 Robinson, F. P. A., "Pitting Corrosion. Cause, Effect, Detection and Prevention," *Corrosion Technology*, 1960, **7**, 237–239, 266.
145 Ketcham, S. J., and Beck, W., "Detecting Intergranular Corrosion Susceptibility in Aluminum Alloys," *Corrosion*, 1960, **16**, 37t–40t.
146 Stadelmeier, H. H., and Whitener, E. M., "Accelerated Corrosion in Aluminum–Silver Alloys," *ibid.*, **16** (3), 20.
147 Godard, H. P., and Cooke, W. E., "The Analyses and Composition of Aluminum Corrosion Products," *ibid.*, **16**, 181t–187t.
148 Knoeller, E. L., and Goodson, J. B., "Leaching Action of High Purity Water on Plastics and Other Materials," *ibid.*, 407t–410t.
149 Bloom, R., Weeks, L. E., and Raleigh, C. W., "Materials of Construction for Equipment Used with Hydrogen Peroxide," *ibid.*, 164t–170t.
150 Raleigh, C. W., and Derr, P. F., "Compatibility of Materials with Unsymmetrical Dimethylhydrazine Rocket Fuel," *ibid.*, 507t–511t.
151 Geiger, R. A., Schuler, F. T., and Mowers, R. E., "Corrosion Considerations in Selection of Rocket Engine Materials," *ibid.*, **16** (1), 30.
152 Aylmore, D. W., Gregg, S. J., and Jepson, W. B., "The Oxidation of Aluminium in Dry Oxygen in the Temperature Range 400–650° C.," *J. Inst. Metals*, 1960, **88**, 205–208.
153 Locking, K. F., "Measurement of Thickness and Porosity of Oxide Films on Iron and Aluminium," *J. Applied Chemistry*, 1960, **10**, 449–456.
154 Capp, R. S., and Philibert, R. J., "Some Corrosion Problems in Ships and their Solutions," *Corrosion*, 1960, **16** (7), **22**, 24, **26**, 28, 30, 32, 34, 38, 40
155 Brooks, R. E., "Corrosion Design in the Marine Application of Aluminum Alloy Floodlights," *ibid.*, **16**, 41t–42t.
156 Heath, W. G., "Designing for Structural Safety," *Sheet Metal Industries*, 1960, **37**, 891–898, 916.
157 Latimer, K. G., "Examination of Corroded Welds in an Aluminium Cooking Vessel, with Recommendations for Improved Welding Techniques," *J. Inst. Metals*, 1960, **88**, 432–434.
158 Oldfield, E. A., and Twigg, D., "Corrosion and Staining of Stainless Steel Knives," *Corrosion Prevention and Control*, 1960, **7** (6), 34–36, 58.
159 Flournoy, R. W., "Underground Aluminum Pipe Line for a Sour Gas Gathering System," *Corrosion*, 1960, **16**, 419t–420t.
160 Collins, H. H., and Higgins, R. I., "The Corrosion of Road Vehicle Engines by Anti-Freeze Solutions," *Corrosion Prevention and Control*, 1960, **7** (3), 36–45, 48; **7** (3), 41–48.
161 Craig, H. L., and Woods, P. H., "Inhibition of Corrosion of the Hypereutectic Aluminium-Silicon Alloys in Anti-freeze Solutions," *Corrosion*, 1960, **16**, 457t–460t.
162 Sundararajan, J., and Char, T. L. R., "Inhibitors for Aluminium in Acid Solution," *Corrosion Technology*, 1960, **7**, 207–208.
163 Sundararajan, J., and Char, T. L. R., "Corrosion Inhibition of Aluminium," *Corrosion Prevention and Control*, 1960, **7** (11), 49–50.
164 Bauer, C. A., and Eddy, L. C., "Cathodic Protection for Metallic Water Tanks," *Corrosion*, 1960, **16**, 390t–394t.
165 Ayres, R. F., "Chemical Conversion of Metal Surfaces for Improved Corrosion Resistance," *Metal Progress*, 1960, **78** (3), 101–107.
166 Wells, F. H., "Chemical and Electrolytic Polishing," *Electroplating and Metal Finishing*, 1960, **13**, 197–204.
167 Pinner, R., "Recent Trends in Electro and Chemical Polishing," *ibid.*, 205–214.
168 Blencowe, H., and Brace, A. W., "Electro-brightening: a Pilot Plant Study of the 'Alullex' Process," *Metal Industry*, 1960, **96**, 231–234.
169 Anon., "Anodising Plant with Automatic Control," *Light Metals*, 1960, **23**, 112–114.
170 Nickelsen, D., "Continuous Anodising and Lacquering," *Metal Industry*, 1960, **96**, 63–66, 70.
171 Howitt, F., and Jenks, I. H., "Improved Aluminum Alloys for Bright Anodising," *Metal Progress*, 1960, **77** (1), 87–91, 168, 170, 174.
172 Hübner, W. W. E., and Schiltknecht, A., "The Practical Anodising of Aluminium," Macdonald and Evans, 1960, pp. 330.
173 Crehan, W. J., "Electroless Process for Chemical Nickel Plating," *Corrosion*, 1960, **16** (4), 23–24.
174 Hammond, R. A. F., and Williams, C., "The Effect of Electroplating on Fatigue Strength," *Metallurgical Reviews*, 1960, **5**, 165–223.
175 Lister, L., and Brace, A. W., "Enamelling Aluminium," *Metallurgia*, 1960, **61**, 61–64.
176 Anon., "Vitreous Enamel and Aluminium at Slough," *Light Metals*, 1960, **23**, 181.
177 Anon., "Plastics Coated Light Metals," *ibid.*, 224–225.
178 Clark, W. D., "Further Data on Atmospheric Corrosion of Aluminium Alloys in a Large Chemical Factory and Their Protection by Painting," *J. Inst. Metals*, 1960, **88**, 406.
179 Anon., "Direct Paint Application," *Light Metals*, 1960, **23**, 267.
180 Anon., "Paint Finishing Outboard Motor Castings," *Metal Industry*, 1960, **96**, 269–270.
181 Andrews, D. R., "The Protection of Iron and Steel by Aluminium Coatings," *Metallurgia*, 1960, **62**, 153–158.
182 Payne, J. H., "Metal Spraying Progress," *Corrosion Prevention and Control*, 1960, **7** (8), 35–37, 40.
183 Curson, G. A., "Important Recent Developments in Metal Spraying," *ibid.*, 41, 43.
184 Nicholls, J. H., "Hot-Dipped Metallic Coatings," *Corrosion Technology*, 1960, **7**, 107–110, 117.
185 Nicholls, J. H., "Hot Dip Aluminised Steel Sheet," *Corrosion Prevention and Control*, 1960, **7** (10), 42–45, 64.
186 Mitchell, K. W., King H., and Brandes, E. A., "The Effect of Protective Coatings on the Properties of Ferritic Steel at 650° C.," *Metallurgia*, 1960, **61**, 15–23.
187 Porter, F. C., "Aluminium 1959," *Corrosion Prevention and Control*, 1960, **7** (1), 33–44.
188 Brierly, F. S. M., "'Canberra': A Study of Superstructures," *Light Metals*, 1960, **23**, 93–95.
189 Anon., "New French Cargo Ships," *ibid.*, 41.
190 Anon., "Aluminium Tanker for Inland Waterways," *ibid.*, 152–153.
191 Anon., "Self-Supporting Double-Skinned Roof Structure," *ibid.*, 96–97.
192 Anon., "First Nuclear Aircraft Carrier to Have Aluminum Elevators," *Corrosion*, 1960, **16**, 34.
193 Anon., "Welded Hatch Covers," *Light Metals*, 1960, **23**, 80.
194 Elliott, E., "Aluminium-Alloy Side Scuttles for Ships," *British Foundryman*, 1960, **53**, 215–220.
195 Anon., "Cast Stand for a Marine Compass," *Light Metals*, 1960, **23**, 58.
196 Anon., "Ships' Fenders," *ibid.*, **22**, 318.
197 Anon., "The 1961 Motor Car," *ibid.*, 313–317.
198 Boghossian, V., "The All-Aluminium Engine," *ibid.*, 298–301.
199 Anon., "New Forward Entrance Double-Decker," *ibid.*, 66–67.
200 Anon., "Pre-Packaged Tipper Bodies," *ibid.*, 57.
201 Anon., "Tipper of All-Welded Construction," *ibid.*, 231.
202 Anon., "Bulk Sugar Transport of New Design," *ibid.*, 125–126.
203 Anon., "Cast-Aluminium Underframe Pedestals," *Foundry Trade Journal*, 1960, **108**, 404.
204 Anon., "Manufacturing the 'Trav-o-Lator' for the Bank Station, London," *Sheet Metal Industries*, 1960, **37**, 512–513, 518.
205 Anon., "Aluminium in Railway Rolling Stock," *Metallurgia*, 1960, **62**, 7–10.
206 Anon., "Light Alloys in Railway Rolling Stock," *Metal Industry*, 1960, **97**, 26–27.
207 "International Exhibition of Aluminium in Railway Rolling Stock," The Aluminium Development Association, 1960, pp. 88.

208 Anon., "The Silver Trains," *Light Metals*, 1960, **23**, 21–22.
209 "Symposium on Aluminium in Building," The Aluminium Development Association, 1960, pp. 252.
210 Johnson, H. W., "Curtain Walling Systems," *Light Metals*, 1960, **23**, 20–21, 51–53, 85–86, 108–110, 143–144, 151–152, 195–196, 227–228, 238–239, 266–267, 296–297.
211 Anon., "Wall Cladding—New System of Attachment," *ibid.*, 26–27.
212 Anon., "Extruded Wall Cladding," *ibid.*, 49.
213 Anon., "Palico Building, Manila," *ibid.*, 170–172.
214 "Aluminium Corrugated and Troughed Sheeting," Applications Brochure 14, The Aluminium Development Association, 1960, pp. 56.
215 Anon., "Aluminium at the New U.S. Embassy Building," *Light Metals*, 1960, **23**, 253–257.
216 Parker, G. R., "Precision Built Light Alloy Houses," *Metal Industry*, 1960, **97**, 3–8.
217 Anon., "ASM Headquarters," *Journal of Metals*, 1960, **12**, 162.
218 Anon., "Aluminium Landing Craft," *Light Metals*, 1960, **23**, 97–98.
219 Anon., "Helicopter Lifts Aluminium Roof," *Metal Industry*, 1960, **96**, 155.
220 Anon., "Roof Capping with Aluminium Foil," *Light Metals*, 1960, **23**, 288.
221 Anon., "New Developments for Windows," *ibid.*, 28.
222 Anon., "Aluminium Doors," *ibid.*, 82–83.
223 Anon., "Aluminium Towers for Communications," *ibid.*, 56.
224 Anon., "Self-Supporting Aluminium Tower," *ibid.*, 8–9.
225 Anon., "Welded Aluminum Pole Withstands Hurricane Forces," *Welding Journal*, 1960, **39**, 1059–1060.
226 Anon., "An Aluminium Church Steeple," *Light Metals*, 1960, **23**, 84.
227 Anon., "Aluminium Device for Bridge Building," *ibid.*, 271.
228 Anon., "Seaside Balustrades and Railings," *ibid.*, 65.
229 Anon., "Continuous Process for Beer-Can Manufacture," *ibid.*, 53.
230 Anon., "Canning Developments," *ibid.*, 261.
231 Elliott, B., "Aluminium Collapsible Tubes," *Corrosion Technology*, 1960, **7**, 171–175, 186.
232 Anon., "Aluminium Cladding on Steam Main," *Sheet Metal Industries*, 1960, **37**, 547.
233 Anon., "High-Pressure Aluminium Pipelines," *Light Metals*, 1960, **23**, 193.
234 Anon., "Aluminium Pipe Formers," *Metal Industry*, 1960, **23**, 379.
235 Anon., "Applications in Brewing," *Light Metals*, 1960, **23**, 302–303, 306.
236 Anon., "Solid Aluminium Conductors," *ibid.*, 55.
237 Anon., "Foil for Solenoids," *ibid.*, 163.
238 Thomas, A. G., and Rata, P. J. H., "Aluminium Busbar," Hutchinson Scientific and Technical, 1960, pp. 105.
239 Anon., "Die-Castings in the IBM Electric Typewriter," *Metal Industry*, 1960, **96**, 247–250.
240 Butler, A. H., and Thomas, J. L., "New Design in Modern Living," *Welding Journal*, 1960, **39**, 1147–1148.
241 Anon., "Die-Cast Gas Cooker and Grill," *Metal Industry*, 1960, **97**, 47–49.
242 Anon., "An Aluminium Mural," *ibid.*, **96**, 197.
243 Anon., "Super Purity Aluminium," *ibid.*, **97**, 223–226.
244 I.S.O. Recommendation R 115, "Classification and Composition of Remelt Ingots and Pigs of Unalloyed Aluminium," International Organisation for Standardisation, July, 1959.
245 I.E.C. Recommendation, Publication 121, "Recommendation for Commercial Annealed Aluminium Electrical Conductor Wire," International Electrotechnical Commission, 1960.
246 Anon., "Resistivity of Aluminium Conductors," *Metallurgia*, 1960, **61**, 106.
247 B.S. 3242: 1960, "Aluminium Alloy Conductors for Overhead Power Transmission."
248 B.S. 2901, "Filler Rods and Wires for Inert-Gas Arc Welding." Part 2: 1960, "Wires for Gas-Shielded Metal-Arc Welding."
249 B.S. 336: 1960, "Couplings, Branch Pipes, Nozzles, Strainers and Auxiliaries for Fire Hose."
250 B.S. 3251: 1960, "Hydrant Indicator Plates."
251 B.S. 2698: 1960, "Containers and Notes for Film Strips."
252 B.S. 3272: 1960, "Aluminium Food Storage Bins."
253 B.S. 3277: 1960, "Thigh Corsets and Cuff Tops for Orthopaedic Calipers."
254 B.S. 3274: 1960, "Tubular Heat Exchangers for General Purposes."

## Oxygen Converter Order

DAVY & UNITED ENGINEERING CO., LTD., has received an order worth about £300,000 from the Broken Hill Proprietary Co., Ltd., for the design and supply of two 200-ton basic oxygen converter furnaces, to be installed at the company's works at Newcastle, New South Wales.

Through their former subsidiary, Duncan Stewart & Co., Ltd., Davy-United have had an interest in the design and manufacture of converters extending over many years, and with the advent of oxygen steelmaking processes they joined forces with British Oxygen to form Davy British Oxygen, Ltd., to operate in this field. Later, Davy-United formed a steel processes division to absorb the personnel of and develop the work previously undertaken by Davy British Oxygen. The recent merger with The Power-Gas Corporation to form the Davy-Ashmore group now enables a substantial proportion of such plant to be manufactured in the Stockton shops of Davy-Ashmore, for which they are well equipped. Further, an alignment between Ashmore, Benson, Pease & Co., Ltd., and the Pennsylvania Engineering Corporation of Pittsburgh, U.S.A., gives Davy-Ashmore access to converter design based on the most modern American converter practice, while still retaining the essential qualification of British manufacture and supply.

The first fruits of these arrangements has been the placing of this Broken Hill order, which represents a new phase in the development of oxygen converter steelmaking, which has hitherto been limited to furnaces of about 100 tons capacity.

## Rolling Mills for E.S.C.'s Tinsley Park Plant

Two Sheffield engineering companies, acting together as a consortium, Davy & United Engineering Co., Ltd. (a member of the Davy-Ashmore group) and The Brightside Foundry & Engineering Co., Ltd. (a member of the Brightside group), have secured a contract worth just over £2¼ million to build rolling mills required for the new Tinsley Park Works of English Steel Corporation, Ltd., the largest single industrial development so far undertaken within the city of Sheffield. This contract covers plant designed primarily for the quantity production of high quality alloy and special carbon steel billets. It consists of a 42 in. × 102 in. blooming and slabbing mill, two 32 in. × 84 in. reversing billet mills, and an extensive range of billet finishing equipment. Provision is being made in the layout of the plant for the subsequent addition of a third billet mill stand at a later date.

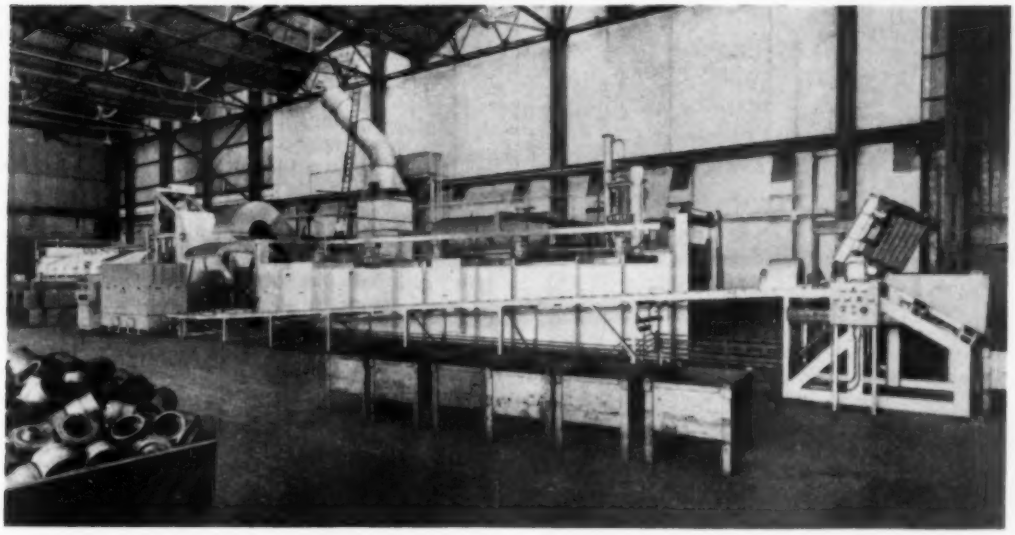
The new plant, which is expected to be in full operation early in 1963, will treble billet output at E.S.C., lifting it from 130,000 to 380,000 tons a year, and will also enable more economical production to be effected. The plant will, however, have a further production facility. In addition to rolling special steel ingots weighing between 2½ and 5 tons for conversion into billets, the blooming and slabbing mill will also be equipped to roll slab ingots of stainless steel weighing 10½ tons to feed the neighbouring hot strip plant of Shepcote Lane Rolling Mills, Ltd., in which E.S.C. have an interest through Firth-Vickers Stainless Steels, Ltd.

English Steel Corporation, Ltd., has placed a further contract, valued at approximately £1 million, with The Brightside Foundry and Engineering Co., Ltd., covering the building of the bar mills at Tinsley Park. This further order is for a highly mechanised and versatile plant specifically designed for the production of alloy and carbon steel bars of high accuracy and quality at high rates of output. It is believed that they will be the most modern of their type in the world, embodying many special features. When completed, total capacity for production of rounds, flats and other sections in alloy and special carbon steels will exceed 100,000 tons per annum.

## Davy-Ashmore Export Company

DAVY-ASHMORE, LTD., have formed Davy-Ashmore Export Co., Ltd., to manage and develop the overseas selling and engineering organisation and to promote a further extension of the group's export trade in capital goods. The directors of the new subsidiary are: Mr. M. A. FIENNES (chairman), MR. D. L. CAMPBELL, M.C. (managing director), MR. D. M. R. BROWN, MR. M. F. DOWDING, MR. T. K. HARGREAVES, D.S.O., MR. C. ROBSON, MR. R. W. RUTHERFORD, MR. H. M. SUTHERLAND and MR. H. H. UTLEY: MR. L. DAVIS is secretary. The new company will operate from offices at 15 Portland Place, London, W.1. (Tel.: Langham 5588).

# Annealing Pearlitic Blackheart Malleable Iron Castings



**General view of the installation from the discharge end with the low temperature furnace nearest the camera.**

THE use of pearlitic blackheart malleable castings in the automobile and allied industries in this country is growing, and Ley's Malleable Castings Co., Ltd., who have been making their Lepaz pearlitic malleable for thirty years, decided some time ago that additional capacity was required. Accordingly, AEI-Birlec was commissioned to build continuous equipment with a minimum capacity of 150 tons per week for Ley's new annealing department. It was emphasised that high quality of product was essential and that design and construction must ensure that the plant run with only routine maintenance from summer holiday to summer holiday. Moreover, automatic operation was to be adopted to ensure consistency and to reduce labour costs to a minimum.

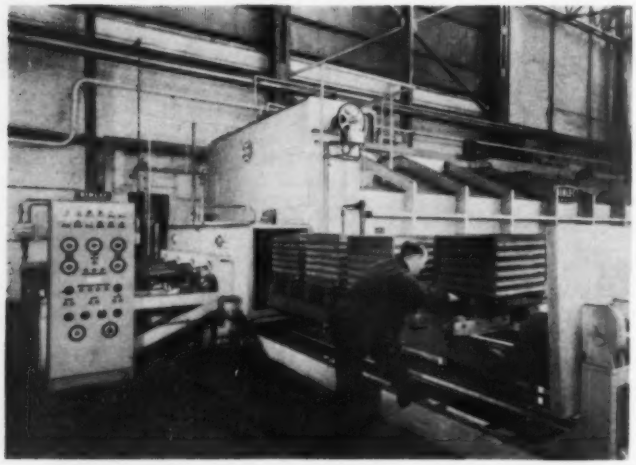
While batch furnaces can be used for the annealing of pearlitic material, the very fast and uniform cooling required after the high temperature part of the annealing cycle to provide high quality can best be obtained by handling in comparatively small quantities in a continuous plant. The equipment has now been operating under normal production conditions for almost a year, and already it is clear that the chief aims have been achieved, in quality of castings produced and reliability in service.

The plant is designed for the scale-free annealing of pearlitic castings at a rate of 1 ton/hour. This is achieved by charging together into the high temperature furnace four trays per hour, each holding about 5 cwt. of castings. These trays are discharged individually, one every 15 minutes, for the castings to be cooled and then progressed through the low temperature furnace. The time/temperature cycle used is as follows: heat to 950° C. in 4 hours; hold at 950° C. for 15 hours; cool to approximately 650° C. in not more than 5 minutes; re-heat to 700° C.; hold at 700° C. for 4½ hours; and cool to handling temperature.

### Plant Details

The plant comprises a furnace for the high temperature part of the cycle, followed by a charge dumper and air blast cooling conveyor and, finally, a low temperature furnace with cooling station and tray discharge gear. Conveyors are included for returning the trays to the charging areas. The furnaces are of the pusher tray design with hydraulic operation and automatic sequencing throughout, the complete plant being operated by two men only, with the necessary occasional supervision by the heat treatment superintendent and laboratory personnel.

*High Temperature Furnace.*—The high temperature furnace has four tracks and is equipped with lock chambers to ensure that the atmosphere in the main chamber is substantially undisturbed during charging and discharging. The charge end lock chamber is designed to accommodate a charging car entering from one side and carrying four trays. It houses also the four pusher heads, which, by means of hydraulic cylinders, progress the lines of trays through the furnace. A vertically rising door communicates with the main chamber. The discharge lock chamber is on similar lines, with skid rails onto which the trays are pushed from the furnace,



**The charge end of the high temperature furnace.**

being discharged one at a time by a cross pusher into a discharge vestibule, from which another pusher projects them onto the dumper table. The necessary doors are operated in sequence with the other movements. The furnace is electrically heated in four zones, with a total rating of approximately 600 kW., nickel-chromium tape elements being used in the roof and Birlec cast grid nickel-chromium elements in the hearth, the latter to resist failure due to build-up of foreign matter.

*High Temperature Tray Dumper.*—The dumper table is lifted hydraulically complete with tray, the action being such that the tray is tilted to an angle for discharge of its contents onto the cooling conveyor. After cooling has been carried out the table returns to its normal position automatically, and the empty tray is passed onto the return conveyor and finally into position for re-charging.

*Cooling Conveyor.*—The cooling conveyor is an inclined unit of the vibrating type. It is fitted in a chamber which forms a duct along its length, with air blown onto the underside by a powerful fan, the hot air being discharged upwards. After cooling to below a chosen temperature, the castings are passed by the conveyor to a tray of larger size than those used in the high temperature furnace ready to go into the low temperature furnace. The use of the large tray avoids the labour of re-packing by hand.

*Low Temperature Furnace.*—This furnace takes a single row of trays, a hydraulic pusher situated under the cooling conveyor being used to convey them through it. The furnace is a straightforward electrically-heated three-zone unit rated at 290 kW., and is fitted with fans to ensure the correct heating conditions. The heating elements are of nickel-chromium tape on the side walls and partly on the roof. Doors are fitted, the one at the charge end being hydraulically operated in sequence with the other operations. The discharge door is left permanently open and is only fitted for use during heating-up the furnace after a shut-down period.

Across the charge end of the furnace there is a section of conveyor extending from the tray return conveyor. In it there are three tray positions in front of the furnace. The first of these is a " tray ready " position into which the operator pushes an empty tray ready for it to be transferred later to the " loading " position. In the latter, an empty tray receives a charge from the cooling conveyor automatically, and is then passed into the furnace as indicated earlier. The third position is used for final cooling off of a tray of castings if other than the normal low temperature treatment is to be given, e.g. re-heating for oil quenching.

*Final Handling.*—Cooling the castings for handling is achieved by air blast as each tray emerges from the furnace. There is an elevator table to receive each individual tray, and at its upper position this table is inclined sufficiently to allow free gravity discharge via a fixed inclined roller track onto a discharge dumper. This dumper discharges the castings into the skip used to take them to the next process and later deposits the tray on the return conveyor, which is inclined so as to take trays back to the charging end of the low temperature furnace by gravity.

*Atmosphere.*—A 2,000 cu. ft./hr. nitrogen generator has been supplied to provide atmosphere for purging the lock chambers after the charging and discharging operations, and to ensure that the atmosphere established in the high temperature furnace is substantially unaffected throughout the heating and soaking period in this furnace. This is most important, as it is desired to ensure that decarburisation is kept to a very low figure in an endeavour to obtain the highest possible quality results. The plant includes a storage vessel for 2 hours supply of gas to enable routine maintenance to be carried out without impairing operation of the furnace, and to provide the short time high rate of flow required for purging the lock chambers.

*Control Gear.*—The usual system of control for power and auxiliary circuits and for temperature has been adopted. The electrical equipment is fully interlocked and incorporates all necessary safety features. The temperature control and recording instruments are accommodated in a very well arranged control room, which also contains the controls for the elevator batch furnaces supplied by AEI-Birlec some years ago. The oil hydraulic pumping and control equipment is contained in a cabinet alongside the furnace, and the main operating controls with sequence switch and timers are in a cubicle at the charge end of the high temperature furnace. Warning devices as necessary to keep the operators informed are incorporated. It is claimed that with such controls in operation, labour costs are low, product quality is high, and reliability of operation is good.

The system of sequence control with a cam type rotary sequence switch in conjunction with hydraulic circuits for multiple movements used in large continuous furnaces was developed by AEI-Birlec engineers. It has been employed many times with complete success, particular earlier examples being for continuous carburising furnaces, some of which have been in operation for nearly ten years.

# Some Results of the Examination of Aluminium Alloy Specimen Fracture Surfaces

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*Fatigue, stress-corrosion and tensile fracture surfaces of aluminium alloy specimens have been examined by optical and electron microscopy. It was observed that fatigue crack growth was an irregular process and dependent on the shape of crack front developed. The nature of fine fatigue fracture striations is discussed and a tentative mechanism for their formation proposed. Brittle intercrystalline tensile fracture in the materials examined was characterised by a dimpled fracture pattern. A mechanism for this mode of failure, involving the growth of lens shaped voids at boundaries and the migration of kink bands, is proposed.*

THE mechanisms by which metals and alloys may fracture have been the subject of much research. Brittle fracture[1] and creep fracture[2] are at least partially understood, and recent work based on the earlier observations of Tipper[3] has led to important advances in the field of ductile transcrystalline fracture.[4] In aircraft materials, particularly the high strength aluminium alloys, fatigue fracture and stress-corrosion fracture are of primary interest. The bulk of the metallographic work on fatigue has concerned the early stages of the process up to the initiation of fracture, propagation studies being largely confined to observations of crack growth rate as measured on the specimen surface. The crack growth period is of the greatest practical importance, since it may occupy more than 80% of the total fatigue life of a given specimen. Similarly, the mechanism of brittle intercrystalline fracture which characterises stress-corrosion cracking in these materials is little understood. This paper describes some observations made on such fracture surfaces by optical and electron microscopy.

## Observations of Fatigue Fracture Surfaces

The main macroscopic features of a classical fatigue fracture are apparent lack of ductility and the presence of "tide marks" on the fracture surface. These are often present as alternate dull and brightly reflecting crescents. Microscopic examination at high powers often shows the characteristic pattern of fine striations or lamellae first observed by Zappfe and Worden,[5] each of which is produced by a single cycle of stress.[6] Fig. 1 shows an example of fatigue fracture striations on a specimen subjected to a single cycle of high stress, seven cycles at a lower stress followed by twenty-seven cycles at a still lower stress. The striations due to each of these stress levels are clearly visible in Fig. 1 and were found

**Fig. 1—Fatigue fracture surface showing striations produced at different stress levels. Optical micrograph. × 2,250.**

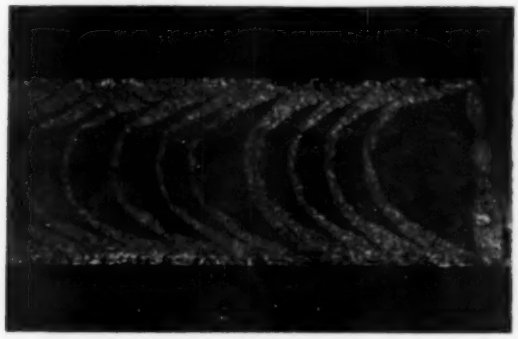

**Fig. 2—Alternate dull and bright progression marks on fatigue fracture surface near origin of failure. Sheet specimen. × 7.**

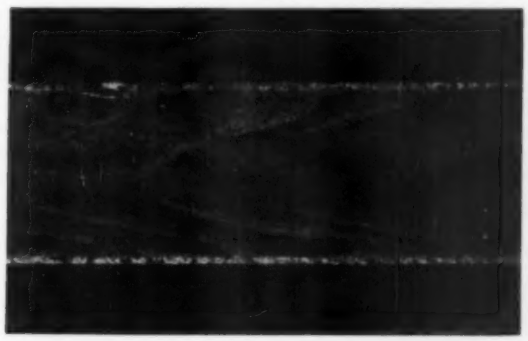

**Fig. 3—Same specimen as Fig. 2 but field 2 in. from origin of failure. × 7.**

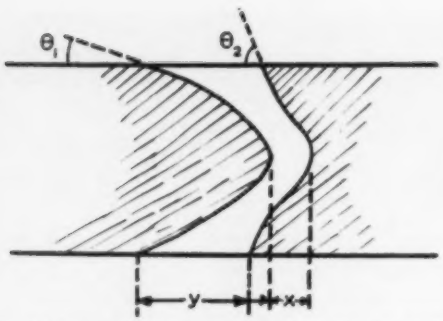


**Fig. 4—Diagram showing change of shape of crack front with change of fracture mode.**

to correspond numerically with the number of cycles of load applied to the specimen.

*The Nature of Progression Marks on Fatigue Fractures*

Alternate dull and bright crescent-shaped progression marks are a common feature of fatigue fracture and their presence has generally been accepted as evidence of variation in the rate of crack growth.[7] Good examples of these markings are shown in Figs. 2 and 3, which are photographs of parts of the fatigue fracture surface of a large D.T.D. 687 sheet. Fig 2 shows the fracture near the origin of failure and Fig. 3 the fracture surface 2 in. from where the crack began. The specimen was tested at 14,000 ± 2,000 lb./sq. in. load and failed after 34,000 cycles. An obvious feature was that the crescent marks, which represented successive positions of the crack front, became progressively more tongue-like as the crack grew. This effect shows most markedly in sheet specimens, but has also been observed in heavy sections of both clad and unclad light alloy. Examination of such specimens at high magnifications showed that fine fatigue striations only appeared on bright zones of the fracture. The dull zones showed only the dimpled pattern which Crussard[8] and others have shown to be characteristic of tensile failure. On a microscopic scale the texture of these zones was identical with that of the tensile failure produced on final fracture of each specimen. It was therefore inferred that fatigue crack growth in such specimens entailed alternate bursts of slow and fast fracture. It was also noted that the shape of the crack front changed during each burst of fracture, as shown diagrammatically in Fig. 4. After each burst of fast fracture the crack front was tongue-shaped and its trailing edges made some angle $\theta_1$, with the edge of the specimen. During the subsequent period of slow growth the tip of the crack advanced a distance $x$, while at the edge of the sheet it grew some much greater distance $y$. During the same period the angle $\theta_1$ changed to some greater angle $\theta_2$. The crack front had in this period tended to shorten itself and develop a double curvature.

*Fatigue Fracture Striations*

The nature of fatigue fracture striations and the

**Fig. 6—Diagram showing the profile of fatigue failure striations.**

**Fig. 5—Fatigue striations on the fracture surface of a duralumin forging. Optical transmission micrograph of polystyrene replica. × 1,000**

mechanism which produces them is not clearly understood. It seems most unlikely however that they are connected with some micro-cellular structure as suggested by Zappfe and Worden.[5] Fig. 5, which shows striations on the fracture of a duralumin forging that failed in service, illustrates many of their characteristics. When examined microscopically with vertical illumination it was observed that striations could be resolved into two parts, a dark band with an immediately adjacent light band. Examination using Tolansky's light profile technique[9] suggested that the contour section of striations is that shown in Fig. 6. An important observation was that mating fracture surfaces did not interlock but peak matched peak. It seems probable that such a profile could arise from a ductile fracture—brittle fracture sequence. Examination of a large number of laboratory and service fatigue failures showed that the proportion of ductile to brittle fracture in an individual striation depended upon the ductility of the specimen as measured in the conventional tensile test. Highly ductile alloys of the aluminium-magnesium type had striations of almost saw-tooth profile with little evidence of brittle behaviour. Aluminium-copper alloys had striations with much smaller peaks, each associated with a substantial region of brittle fracture. In the aluminium-copper-zinc-magnesium alloys, even less local ductility was shown and striations were frequently not resolved by the optical microscope. It was noted that

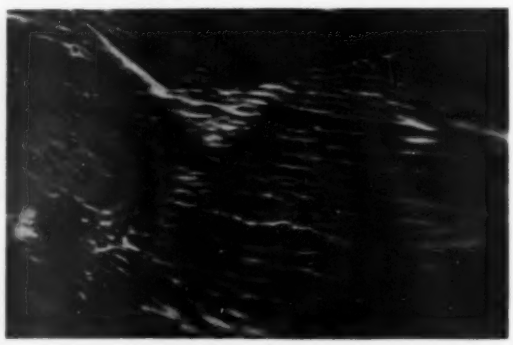

**Fig. 7—Fatigue fracture surface, lightly electro-polished and etched, showing traces of striations. Aluminium-4% copper alloy. × 1,000**

Fig. 8—Stress-corrosion fracture surface of D.T.D. 683 forging showing dull and bright crescent-shaped progression marks. × ¾ (approx.)

Fig. 9—Bright zone of stress-corrosion fracture surface showing polygonal pattern produced by small local tilts. Electron micrograph. × 7,500

the plateaux, upon which striations are most easily observed, were separated by steps or valleys, and in many cases local origins of failure were seen which generated fan-shaped plateaux (Fig. 5). This photograph also illustrates the observation that fatigue crack fronts were often of irregular shape with local variations in the direction of crack propagation. Lightly electropolished and etched fatigue fractures have been examined and it appears that each fatigue striation may be associated with a deformation band. A typical example of a polished and etched fracture is shown in Fig. 7. In duralumin alloys these deformed zones were sometimes regions where re-solution of precipitate had occurred.

### Examination of Stress-Corrosion and Intercrystalline Tensile Fractures

Stress-corrosion fractures and fatigue fractures in light alloys have many similarities, in that both may show crescent-shaped progression marks, both occur with little overall elongation, and both spread under tensile loads. Fig. 8 shows a stress-corrosion fracture in a D.T.D. 683 aluminium-zinc-magnesium-copper alloy forging. It was noted in this specimen that changes of shape of crack front had occurred as the crack progressed that are directly analogous to those described for the D.T.D. 687 sheet fatigue specimen. Microscopic examination of the brightly reflecting zones of stress-corrosion fractures showed that they were the result of intercrystalline fracture with little accompanying plastic deformation, so that the boundary surfaces of individual grains had retained a high degree of perfection. A fine polygonal network was sometimes observed on such surfaces, with small but sharp tilts between adjacent cells (Fig. 9). It is probable that this pattern was produced by fracture through main grain boundaries intersected by sub-boundaries in the manner shown diagrammatically in Fig. 10.

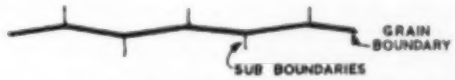


Fig. 10—Diagram showing how small tilts might be produced by the interaction of sub-boundaries with a main grain boundary.

The dull zones of stress-corrosion fractures, which are produced by more rapid fracture than the light zones, were characterised by a dimpled pattern which Crussard *et al*[8] have shown to be characteristic of ductile transcrystalline fracture in a number of metals and alloys. The dimples were small saucer-shaped depressions in the fracture surface, often with a small particle of intermetallic compound at the centre. These depressions are probably much shallower than those produced in ductile

Fig. 11—Dull zone of stress-corrosion fracture showing shallow depressions, often with central inclusion. Electron micrograph. × 7,500

Fig. 12—Isolated depressions on an otherwise smooth boundary facet. Electron micrograph of stress-corrosion fracture surface. × 7,500

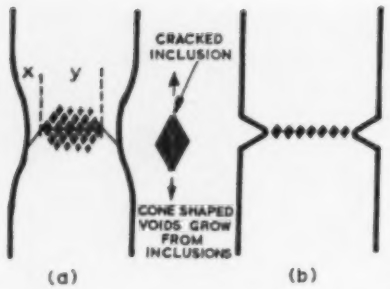


**Fig. 13 (left)—**
**Showing fracture behaviour of a ductile material with a uniform distribution of crack-initiating particles: (a) cup and cone fracture; (b) limited ductility due to notch.**

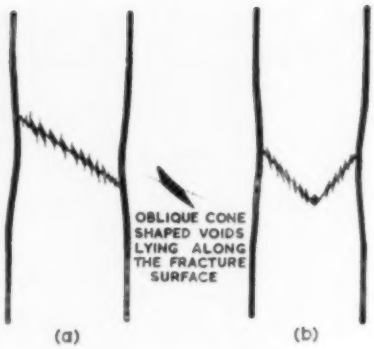


**Fig. 14 (right)—**
**"Shear decohesion" in a low ductility material: (a) single shear; (b) double shear. This behaviour is characteristic of sheet material.**

transcrystalline fracture; Fig. 11 shows dimpled pattern in the dull zone of a stress-corrosion fracture. A number of tensile specimens of aluminium-zinc-magnesium alloy, heat treated so as to give a brittle intercrystalline fracture, were broken and examined. The dimpled pattern was again observed and this suggests that the dull areas of stress-corrosion fractures are produced by normal tensile fracture. It was possible, by examination of mating tensile fracture surfaces, to demonstrate that each dimple was matched by a similar depression on the other half of the fracture. The intercrystalline fracture with perfectly developed facets and the overall dimpled pattern seemed to represent two extremes of behaviour. Intermediate regions where a few depressions occurred on an otherwise perfect boundary surface were quite often observed and an example is shown in Fig. 12.

## General Discussion

Observations on a number of fractures produced in different materials by various forms of stressing have revealed a number of common features which can now be rationalised into a general mechanism of ductile fracture.

It has been shown that textural variations on fracture surfaces are usually due to varying amounts of plastic deformation associated with fracture. This concept has been useful in classifying the various parts of fractures into slow and fast; fast fracture producing considerable associated plastic deformation and slow fracture being more brittle. At one end of the scale we see the highly brittle behaviour of stress cracking where featureless boundary-facets are observed, and at the other end the highly ductile behaviour of tensile fracture. A continuous transition of behaviour from the two extremes has now been established. The fatigue case can be fitted into this general pattern as will be shown later.

It is convenient to consider first the highly plastic behaviour occurring in a ductile material pulled in tension. It has been shown that in the absence of internal crack initiators a tensile specimen may neck down almost to a point before fracturing. In the more general case where internal crack initiators are present, a smaller external reduction in area occurs, but the final fracture in regions of triaxiality occurs by the formation of internal holes with necking and thinning occurring between the holes.[4, 10]

Fig. 13 shows in schematic form the two essential parts of a ductile fracture, the external shear decohesion cone[11] and the central zone of hydrostatic stress where holes have formed, mainly at inclusions. These holes grow by local necking and the intervening material eventually fails by extreme thinning. Fig. 14 represents a common case observed in light alloys and particularly in sheet materials where no active zone of triaxiality exists and the fracture is completely by shear decohesion. Most of the area of tensile fracture of a bulky component, e.g. a wing spar, would be under hydrostatic tension equivalent to zone *y* in Fig. 13*a* and a narrow zone of shear decohesion is usually evident around the edge of the fracture. This formation of holes can be confirmed by an examination of a typical tensile fracture in a

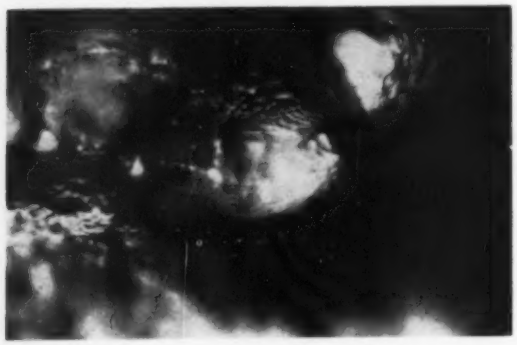

**Fig. 15—Group of adjacent voids on the fracture surface of a ductile material broken in tension. × 1,006.**

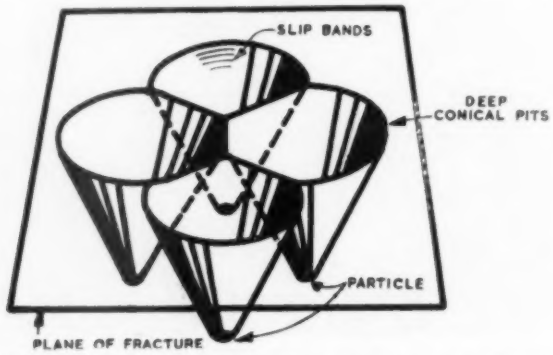


**Fig. 16—Diagram showing the interaction of adjacent conical voids typical of the central portion of a ductile fracture.**

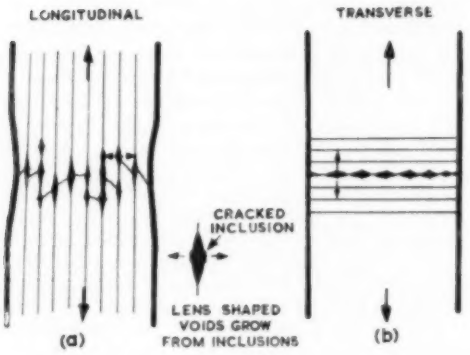


**Fig. 17—Diagram showing behaviour of a bulky specimen of fibrous low-ductility material; (a) stressed parallel to fibre direction; (b) stressed perpendicularly to fibre direction.**

region of triaxiality. The fracture can be seen to be composed of many conical pits, and usually a small inclusion can be seen at the bottom of each pit. The steep surfaces of these pits are covered with slip bands. Fig. 15 shows typical pits and Fig. 16 schematically illustrates how these pits may be associated to form a final fracture zone which is the edges of adjacent craters.

It is interesting to consider that the measured elongation of a specimen depends to some extent on the spatial distribution of crack initiators. If they are homogeneously distributed in depth then extensive deformation can occur because all of the local plastic strains are additive and free slip paths form between holes at various levels. This is illustrated in Fig. 13*a*. If on the other hand the crack initiators are aligned in planes normal to the tensile stress direction, as shown in Fig. 17*b*, then negligible measurable extension of the specimen occurs. If the distribution is homogeneous but the specimen is notched, then the localisation of deformation limits the active initiators to a narrow zone across the specimen and the local deformations are not additive in the direction of the tensile stress. This is shown in Fig. 13*b*.

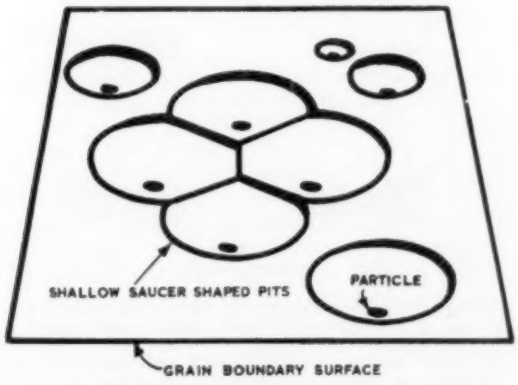


**Fig. 19—Showing interactions of adjacent lens-shaped voids to form dimpled pattern.**

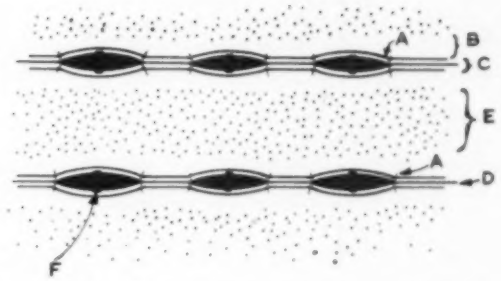


**Fig. 18—Diagram showing mechanism of brittle intercrystalline fracture in a transversely stressed light alloy: (A) kink bands; (B) zone free from coarse precipitate; (C) denuded zones; (D) grain boundary; (E) relatively hard constraining grains; (F) inclusions that initiated fracture.**

In the common case where the active crack initiators are distributed in planes parallel to the tensile direction, then a fibrous fracture occurs that can be almost exactly fitted together, unlike the central zone of a ductile tensile fracture. This type of structure is commonly found in high strength aluminium alloys. The crack initiators in such cases are almost certainly flat particles lying in grain boundaries, sometimes disposed as stringers as shown in Fig. 17*a*. It is also probable that gas cavities which have been spread into flat voids by the deformation processes of manufacture also lie in these boundaries and aid the fracture process. In these materials no deep deformation pits form when transversely stressed because of the restriction in available deformation volume. This has already been referred to in the paragraph on tensile fracture. This restriction in available deformation volume is partly due to the spatial disposition of the crack initiators and also to the fact that they lie in softer boundary zones which are surrounded by harder alloy (see Fig. 18). In the place of the deep deformation pits we see shallow saucer-like depressions on the fracture surfaces as already described. These differences in behaviour are illustrated in Fig. 19. A steadily growing crack from one edge source will, however, faithfully follow the boundary, as shown in Fig. 20.

It will thus be evident that there is a continuous transition of behaviour from brittle grain boundary fracture to what is generally considered fully ductile behaviour as exhibited in a cup-and-cone fracture.

*Fatigue Fracture*

From the evidence presented it is clear that the alternate dull and bright zones visible on fatigue fractures examined at low magnifications result, respec-

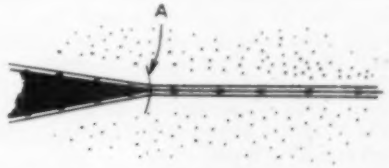


**Fig. 20—Showing how cracking from an edge produces boundary surfaces of high perfection.**

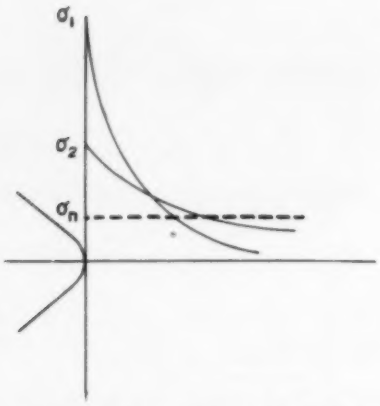


**Fig. 21—Stress distribution at the root of a notch : ($\sigma_n$) nominal stress ; ($\sigma_1$) stress distribution for a sharp notch ; ($\sigma_2$) stress distribution for notch blunted by plastic flow.**

tively, from fast tensile and slow fatigue crack growth. The observation that fatigue crack fronts become tongue-shaped as the crack becomes long, is explained by Cottrell's analysis of fast ductile fracture in sheet materials, and will not be discussed here.[1] During a period of slow crack propagation, however, growth is more rapid near the surface of the sheet than at the centre. This may be due to the high stress concentration at the trailing edge of the crack or to the high shear-stress/normal-stress ratio near the surface of the sheet as compared with that obtaining at the crack tip, which is a region of plastic constraint. The high shear stress ratio would favour plastic deformation, which appears to be an essential feature of the fatigue process. The variation of growth rate along the crack front eventually leads to an unstable configuration and a burst of fast fracture ensues. During this burst of fracture the shape of the crack front changes to become more tongue-like. Besides becoming longer, a greater proportion of the length of the front will lie in the relatively ductile sub-surface layers of the specimen where marked plastic deformation accompanies fracture. This is equivalent to an increase in the plastic deformation component of the complex surface energy term in the modified Griffiths equation. Fast fracture will thus stop when a stable shape of crack front is achieved. The extent of any damage ahead of the crack tip during the preceeding period of slow growth may also influence the exact position of arrest. Some overshoot of this position must occur for, if a just-stable configuration were achieved, only a few subsequent cycles of stress would be needed to produce again an unstable crack, instead of the several hundred required in practice. It is evident that shape of crack front is a most important feature of the fatigue fracture process, and surface observations may well give a false picture of bulk behaviour. It likely that non-propagating fatigue cracks of the type observed by Frost and Phillips[12] may be due in part to an initially unstable crack developing a stable shape of the type described. This discontinuous behaviour would also explain the " dormant period " of crack growth described by Frost and Dugdale.[13]

The microscopic observations show that on a fine scale fatigue fracture is a very irregular process. Local differences of level, shape of front, direction, and rate of growth may all occur in immediately adjacent areas.

The striations which are a common feature of the fatigue fracture of ductile aluminium alloys have already been described. Their formation can now be more readily understood in the light of the observations on tensile fracture. It is first necessary to consider in some detail the behaviour of a plastic material at the root of an external notch. It is known that the Neuber stress distribution for an elastically behaving material is modified when plastic deformation occurs in the root of the notch. This modification has been considered by a number of workers.[14,15] The main effect of the plastic deformation is to reduce the maximum root stress. It also reduces the stress gradient and increases the mean stress over a larger volume of material. The Neuber stress distribution of a sharp-rooted crack will thus be a steep stress gradient, and any plastic deformation which blunts the root of the crack will alter the gradient as shown in Fig. 21. It has been stated that the striation appears to be part ductile and part brittle behaviour. This mechanism of formation can now be discussed in more detail. The deformation at the root of a fatigue crack stressed in tension will cause blunting which, by virtue of the plastic strain involved and the increase in the effective radius at the root of the crack, causes an increase in the mean stress in an increased volume of material ahead of the crack, i.e. the total strain energy of an arbitrary volume of material ahead of the crack is increased. This constrained volume is being hydrostatically stressed in tension ; therefore the ratio of tensile to shear stress is high. Voids form as in normal tensile stressing, but due to the configuration of the crack the affected zone lies ahead of and parallel to the crack front. The second stage in the process is one of plastic flow of the bridge between the crack root and the long void ending in final ductile failure under biaxial conditions. This behaviour is illustrated in Fig. 22.

It is not suggested that the proposed mechanism of fatigue crack propagation is universal. The present observations suggest rather that the fatigue process may consist of at least three stages :—

(1) The initiation of cracks by a slip-governed process possible at fluctuating nominal stresses above some critical value A.

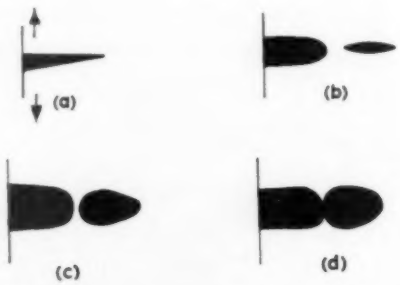


**Fig. 22—Fatigue crack growth during one cycle of stress : (a) end of compressive half cycle, which may have cracked inclusions ahead of crack tip ; (b) tensile half cycle blunts crack tip and produces void ahead of crack in region of triaxial tension ; (c) thinning of unfractured bridge under biaxial tension ; (d) final separation of bridge by thinning.**

(2) The growth of the crack so formed by a process producing fracture on crystallographic planes. This would require a stress B > A since the crack would have to pass through such obstacles as unfavourably oriented grain boundaries.

(3) The further growth of the crack by a process of the type that produces the characteristic Zappfe and Worden striations governed by a normal stress criterion. This would require a stress C > B.

An essential feature of this model is that any two of the stages may be omitted, although either 2 or 3 must operate if final fracture is to occur. For example, in a notched specimen tested at a high stress, stage 3 propagation may operate from the beginning of the test. Considering the stages in more detail, there is good evidence that cracking may initiate in the first few per cent. of a fatigue specimen's life.[17] Since the governing process is one of slip, crack initiation should be possible at all stresses above that required to exceed the critical resolved shear stress in the most favourably oriented surface grain. This value will be low since surface grains may behave as partially constrained single crystals.[18] It is suggested that such cracks are not likely to exceed one grain diameter in length if the stress is only just above the initiation value. There is thus the possibility of producing non-propagating cracks at this stage. If, however, the stress is sufficiently high the crack may propagate into adjacent grains by the stage 2 slip process. The only processes tending to aid such growth will be the progressive increase in length of the growing crack. A number of effects may however inhibit such crack growth, e.g. work hardening and strain ageing. It is now convenient to consider the fatigue specimen as a tensile test piece containing a slowly growing Griffiths crack.

There will be a progressively increasing tendency for the advancing crack to be blunted by plastic deformation. This will entail the development of hydrostatic tensions in the material ahead of the crack. There are two important results of this :—

(*a*) Development of hydrostatic tensions reduces the shear-stress/normal-stress ratio ahead of the root of the crack, and this tends to inhibit glide processes.

(*b*) Plastic deformation at the root of the crack will reduce the peak stress and stress gradient as previously described.

It is suggested that a crack growing in this way will tend to be stopped because it is becoming blunter and encountering a stress system that does not favour glide. On the other hand the conditions tending to inhibit stage 2 propagation will favour the stage 3 growth of the type producing fracture striations. If the stress at this stage exceeds C the crack will propagate, if it does not the crack will become non-propagating.

While such a model has several defects, for example it ignores the shape of crack front developed, it can explain several features of the fatigue process :—

(1) It provides a reasonable explanation of non-propagating cracks.

(2) It accounts for the observation that fatigue fractures are highly faceted, and presumably crystallographic, near their origins and become of rougher texture as the crack grows.

(3) It explains an observation of Stubbington's[18] who found that corrosion fatigue fractures propagated on planes of high shear stress if tested at stresses below the air fatigue limit. This also justifies putting C > B.

(4) This mechanism could reconcile the apparently contradictory observations that while cracks initiate at a very early stage, they only propagate at a macroscopically detectable rate during the last part of a specimens life.

It is thought that there may be no sharp transition from stage 2 to stage 3 but that the change is gradual. Examination of the surfaces of non-propagating cracks would be a useful step in verifying this hypothesis.

*Stress-Corrosion and Brittle Intercrystalline Tensile Fracture*

The observations on stress-corrosion fractures suggest that shape of crack front is again important. The results from examination of the bright areas of stress-corrosion failures here provided no positive evidence of the mechanisms involved. The dull zones of stress-corrosion fractures and the brittle intercrystalline tensile fracture of high strength light alloys are both characterised by a dimpled pattern when examined at high magnifications. The evidence suggests that cracks initiate at particles in or near boundaries, and that the cracks grow to form lens-shaped voids in the manner shown in Fig. 18. There is again evidence that the growth of the voids is accompanied by the migration of kink bands at the crack tip. Kink bands of this type would tend to retard crack growth and may be regarded as additive to the deformation component in the numerator of the Griffiths equation. This concept is in agreement with the observation that minimum ductility coincides with peak hardness in the light alloys that fail in this manner. At peak hardness the grains are not readily deformed and the denuded zones adjacent to grain boundaries are so narrow as to limit plastic deformation in them. The lens-shaped voids which initiate fracture would, in this condition, be shallow, and the kink bands associated with them small and containing relatively few dislocations. This would lead to low strains to fracture and low true fracture stresses. The solution treated condition would allow plastic deformation in the grains and the over-aged condition deformation in both grains and denuded zones. The mechanism proposed is directly analogous to that proposed by Griffiths to explain the fracture strength of glass.[16] The essential difference is that the concept of pre-existing Griffiths cracks is replaced by lens-shaped voids that grow during straining until enough of them exceed some critical size and catastrophic fracture occurs.

## Conclusions

The crack propagation behaviour of high strength light alloys, under conditions that cause failure by stress-corrosion or by fatigue, is influenced by the shape of the crack front developed, which itself is influenced by specimen geometry. The effects may result in irregular crack growth. In both types of fracture brightly reflecting surfaces are produced by slow crack growth and dull surfaces by fast cracking.

The striations observed on fatigue fracture surfaces are of complex structure and could be produced by a brittle-fracture/ductile-fracture sequence in which voids are formed ahead of the crack tip. Their formation may, in

certain alloys, be accompanied by metallurgical changes such as re-solution of precipitate.

The dull zones of stress-corrosion fractures and brittle intercrystalline tensile fractures of high strength light alloys are produced by the same mechanism. This involves the growth of lens-shaped voids at grain boundaries to an extent that ultimately allows catastrophic failure. The mechanism is analogous to that proposed by Griffiths to explain the fracture strength of glass.[16]


### Acknowledgments

The authors are indebted to many of their colleagues, particularly Mr. A. C. Smale and Mr. R. N. Wilson for assistance with the experimental work and helpful discussion. Published by permission of H.M. Stationery Office. Crown Copyright Reserved.



REFERENCES.

1 Cottrell, A. H., *Trans. Met. Soc. A.I.M.E.*, 1958, 211, 196.
2 Davies, P. W., and Dennison, J. P., *J. Inst. Met.*, 1958, **87**, 119.
3 Tipper, C. F., *Metallurgia*, 1949, **39**, 133.
4 Cottrell, A. H., "Fracture: Proceedings of an International Conference on the Atomic Mechanism of Fracture held at Swampscott, Mass., U.S.A., from 12th to 16th April, 1959." Published jointly by Technology Press of Massachusetts' Institute of Technology; John Wiley & Son, Inc., New York; and Chapman & Hall, Ltd., London. p. 20
5 Zappfe, C. A., and Worden, C. D., *Trans. A.S.M.*, 1951, **43**, 958.
6 Forsyth, P. J. E., and Ryder, D. A., *Aircraft Engineering*, 1960, **32**, 96.
7 George, C. W., *J. Birm. Met. Soc.*, 1947, **27**, 308.
8 Plateau, J., Henry, G., and Crussard, C., *Metaux Corrosion Ind.*, 1958, **392**, 141.
9 Tolansky, S., Properties of Metallic Surfaces, Inst. Met. Monograph and Report Series, No. 13, p. 14, 1952, London.
10 Puttick, K. E., *Phil. Mag.*, 1959, **4** (44), 964.
11 Crussard, C., *et al.*, "Fracture: Proceedings of an International Conference on the Atomic Mechanism of Fracture held at Swampscott, Mass., U.S.A., from 12th to 16th April, 1959." Published jointly by Technology Press of Massachusetts' Institute of Technology; John Wiley & Sons, Inc., New York; and Chapman & Hall, Ltd., London. p. 524
12 Frost, N. E., *Engineer*, 1955, **200**, 464.
13 Frost, N. E., and Dugdale, D. S., *J. Mech. and Phys. Solids*, 1957, **5** (3), 182.
14 Fischer, G., *Jahrbuch der deut. Luftfahrtforschung*, 1938, **1**, 517–523.
15 Paterson, M. S., The Failure of Metals by Fatigue, p. 316, 1946 (Melbourne University Press), Melbourne.
16 Griffiths, A. C., *Phil. Trans. Roy. Soc.*, 1920, **A221**, 163.
17 Parker, E. R., and Fegredo, D., Conference on Internal Stresses and Fatigue in Metals, Detroit, 1958 (Elsevier Publishing Co.), p. 273.
18 Rogers, H., *Acta Met.*, 1959, **7**, 750.


### Addendum

Since this paper was written, further evidence has been obtained on the profile and nature of striations. The ductile fracture region of the striation may occur by 45° 'shear'. This will produce completely mating fracture surfaces rather than a peak-to-peak fit. However, the basic principle of the crack growth being composed of a ductile and a brittle component remains unchanged.

## Continuous Casting for Shelton

An order for what is believed to be the largest installation in the world for the continuous casting of steel has been placed by Shelton Iron and Steel, Ltd., of Stoke-on-Trent, with Distington Engineering Co., Ltd., of Workington, a subsidiary of The United Steel Cos., Ltd. The plant is being built under licence from Concast A.G., of Zurich, who are associates of Distington in the field of continuous casting. It will consist of four vertical continuous casting machines with a total of thirteen strands, equipped to cast billets in a large variety of sizes.

Steel for the new installation will be produced in two 45-ton Kaldo converters and will be transferred by ladles to the continuous casting bay. The ladles will be lifted to the top of the casting plant and the liquid steel will be bottom poured into tundishes feeding direct into water-cooled moulds. After leaving the spray cooling chambers and the withdrawal rolls, billets less than 7 in. thick will be bent through 90° and discharged on to roller tables; billets over 7 in. thick will be cut to suitable lengths during their descent and discharged by baskets to roller paths. After reheating, the billets will be fed into a new modern universal beam and section mill. When the new plant is completed, Shelton Iron and Steel will be the first integrated steelworks in this country to depend entirely on continuous casting for its semi-finished steel.

## Vacuum Melting Steel

After extensive trials Hadfields, Ltd., have decided to install at their East Hecla Works a large scale unit for vacuum melting by the consumable electrode technique. The equipment, which will be capable of producing ingots with a weight range of 2–9 tons, is being supplied by Stein and Atkinson, Ltd., to the design of their associated company, the Lectromelt Furnace Division of the McGraw-Edison Company, U.S.A., and will be housed in a new building upon which work has already begun. We are informed that when completed it will be the largest furnace of its type in Europe. This new technique offers substantial advantages over conventional air melting processes, including a greater degree of cleanness in respect of non-metallic inclusions, exclusion of contaminant elements associated with air-melting, removal of undesirable gases dissolved in the metal, improved uniformity and soundness of the ingots, and improvement in mechanical properties.

## TV Monitoring of Process Measurements

Demonstrations of the use of closed-circuit television for monitoring process measurements—as an alternative to conventional telemetering—were held recently, under the auspices of Woodall-Duckham Construction Co., Ltd., in the main instrument-panel assembly department of George Kent, Ltd. The TV equipment was provided by Pye, Ltd., of Cambridge. Visitors, who included senior engineers of the gas industry, were able to see for themselves comparisons of picture clarity in various light-intensity environments with camera equipment providing panoramic and close-up shots in association with 8½ in. and 14 in. standard monitors and a 14 in. high-precision monitor.

Wild-Barfield Electric Furnaces, Ltd., have received an order from L. H. Newton, Ltd., of Birmingham, for a continuous shaker hearth furnace installation. The equipment will be charged automatically and work untouched by operators as it is progressed through hardening, quenching, washing, tempering and final quenching for delivery into collecting baskets at the rate of 600 lb./hr.

Following on the introduction of the new industrial tool, Firth Cleveland Tools, Ltd., a member of the Firth Cleveland group, have formed an industrial division, represented in the field by its manager, Mr. M. H. Withers, Mr. H. F. Lane, formerly a senior Surform representative, and Mr. K. A. Lauder, all of whom are trained engineers.

# The Adhesion of Sprayed Molybdenum

By R. T. Allsop, T. J. Pitt and J. V. Hardy

*G.K.N. Group Research Laboratory*

*A study has been made of the interfaces between sprayed molybdenum and mild steel, cobalt and Brightray bases. The use of chromium as a base material was abandoned when it was found that a molybdenum deposit was only weakly adherent. Examination of the interfaces using both optical and electron microscopy revealed that interfacial layers were present between the molybdenum deposit and the steel, cobalt and Brightray bases. The X-ray scanning microanalyser indicated that the layer between the molybdenum deposit and the steel base was probably an alloy of molybdenum and iron. It is suggested that in cases where sprayed molybdenum adheres to a smooth base either or both of two mechanisms of adhesion may operate ; one is the formation of an alloy layer between base and deposit, the other is the infiltration of fused metal from the basal surface into the pores of the deposit.*

THE preparation of a metallic surface to receive a sprayed metal deposit generally necessitates the roughening, in some way, of the surface in order to ensure that the deposit is adherent. This requirement frequently gives rise to difficulties, particularly where the usual technique of shot blasting is impracticable—e.g. on hardened steel surfaces—or where the surface roughening produced has an adverse effect upon the mechanical properties of the component. One method of preparing a steel surface, without resorting to shot blasting, which has been studied recently, is that of applying a thin underlay of molybdenum prior to the application of the required coating. The success of this method stems from the fact that sprayed molybdenum has the somewhat unusual characteristic of adhering strongly to a clean, smooth steel surface. At the same time the exposed surface of sprayed molybdenum is particularly suitable for receiving sprayed layers of other materials.

The reason why such a strong bond develops between sprayed molybdenum and a smooth steel base has been the subject of considerable conjecture. Several investigators[1,2] have suggested that an alloy layer is formed between the deposit and the base metal. In only a limited number of instances, however, has any photographic evidence been produced to substantiate this view. Even in these cases, the limitations of the optical microscope did not permit the very thin films observed to be clearly resolved.

In view of the considerable interest in the high adherence of molybdenum to a smooth steel surface it was decided to examine, using both the optical and the electron microscope, the interface between sprayed molybdenum and a mild steel base. The investigation was later extended to study the interfaces between sprayed molybdenum and cobalt, Brightray (80% Ni–20% Cr) and chromium bases. It was also possible to employ, to a limited extent, the scanning X-ray microanalyser for analysing chemically one of the layers observed.

## Materials Used

*Base Materials*

The metallic bases employed were as follows :—

(*a*) mild steel plates 2 × 2 × $\frac{1}{8}$ in. thick ;

(*b*) cobalt plates 2 × 1 × $\frac{1}{8}$ in. thick, produced by electrodeposition ;

(*c*) a nickel-chromium alloy (Brightray) in the form of $\frac{1}{8}$ in. diameter wire ;

(*d*) chromium 0·020 in. thick (deposited on to mild steel).

The mild steel surfaces were prepared in two ways, by chemical polishing (as described in Reference 3) and by emery polishing to the "600" grade. The surfaces of the cobalt, Brightray and chromium specimens were prepared by polishing to the "600" emery grade.

*Sprayed Molybdenum*

Molybdenum in the form of 2 mm. diameter wire was sprayed from a Mark 33 pistol, supplied by Metallisation, Ltd. Acetylene was supplied at 15 lb./sq. in., oxygen at 23 lb./sq. in. and air at 45 lb./sq. in. Flowmeters were used to control the nature of the flame and the spraying distance was 6 in.

## Examinations

(*a*) *Optical*

Sections through each of the sprayed samples were taken, mounted in a cold setting plastic (Araldite) and metallographically polished. The sections were etched in a manner indicated in the figure captions and examined under the optical microscope at 1,225 diameters magnification.

Both the emery polished and chemically smoothed mild steel specimens showed a thin interfacial layer (Fig. 1 and 2). With cobalt and Brightray bases the etched specimens also showed thin layers between the deposit and base (Fig. 3 and 4). When molybdenum was sprayed on to chromium little, if any, adherence to the polished surface could be obtained, the deposit separating easily from the base during sectioning. Micro-examination failed to reveal any interfacial layer. An extensive gap, indicative of poor adhesion, was observed between the molybdenum and the chromium.

(*b*) *Electron Microscopy*

In order that the interfacial layers seen with the optical microscope could be observed in greater detail, an electron microscope study of the sprayed specimens was undertaken. For this purpose a Metropolitan-Vickers EM6 microscope was employed. This work confirmed, beyond doubt, that interfacial layers exist between sprayed molybdenum and steel, cobalt and Brightray bases.

Two-stage formvar-carbon replicas were made from

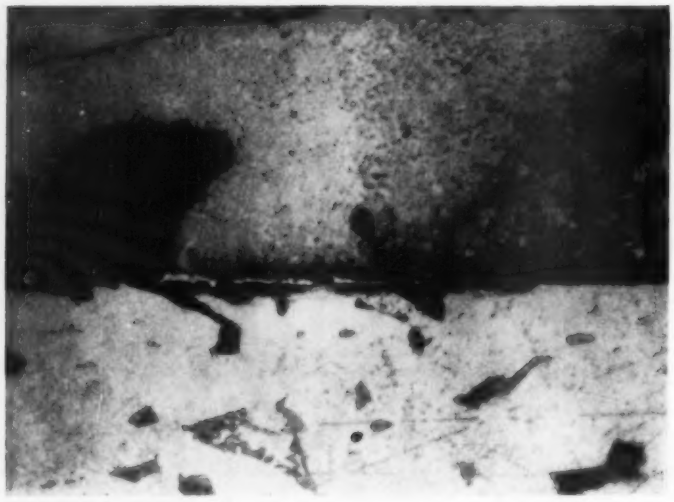


**Fig. 1.—Optical micrograph showing sprayed molybdenum on emery-polished mild steel. Etching reagents : molybdenum—alkaline ferricyanide ; mild steel—nital. × 920**

the etched sections previously examined with the optical microscope. Stripping the primary formvar replica was found to be difficult in most instances due to the porous nature of the molybdenum, and to the cracks and gaps which occurred along the interface. In the case of chromium, the extensive gap prevented any suitable replicas from being taken of the interfacial region.

This difficulty was overcome for steel, cobalt and Brightray bases by using more concentrated solutions of formvar (2½% in chloroform instead of the usual ½–1%) which gave rise to thicker stronger replicas which could be stripped without rupturing. Carbon was deposited normally onto the structure surfaces of the formvar replicas, using Bradley's vacuum evaporation technique,[4] and then the formvar was dissolved away with chloroform.

The carbon replicas were shadowed with 60% gold-palladium alloy at angles of $\tan^{-1} 1$ or $\tan^{-1} \frac{1}{2}$ in order to improve contrast and the rendering of surface relief. The shadowing was performed onto the free surface of each replica in order to avoid shadows cast by the specimen-support grid and thus obtain a greater observable area. It should be remembered when examining the accompanying electron micrographs that this technique produces a negative replica, i.e. one in which elevations appear as depressions, and vice versa. A further consequence of heavy-metal shadowing is that in a normal print from a plate exposed in the electron microscope, shadows appear as light areas. If these points are remembered when interpreting the electron-micrographs, it is evident that the interfacial layers are in fact elevated above the general level of the specimens, that is, they are more resistant to etching. Typical electron micrographs are shown in Figs. 5–10. The markings indicate 1 micron unless stated otherwise (1 micron $= \mu = 10^{-4}$ cm.).

In addition to confirming the presence of the interfacial layers, the electron microscope also revealed that small outgrowths from the layer extended into the molybdenum deposit (Fig. 9). In the case of Brightray, larger outgrowths were also seen occasionally which were visible even in the optical microscope (Figs. 4 and 10). No similar outgrowths into the base metals were observed. It would appear that, for the effect to occur, the interfacial layer must, at some stage, be in the liquid condition. Possibly, the liquid metal is drawn into the pores of the molybdenum by capillary action ; the lack of porosity in the base materials could account for the absence of these outgrowths into the base.

Another interesting effect was observed in the interfacial layer on Brightray, and appears in Fig. 8. A trace of the prominent grain-boundary in the Brightray apparently continues across the layer. This phenomenon is not typical, however.

(*c*) *X-ray Microanalyser*

The results obtained so far have shown quite clearly that etching will reveal a narrow layer between molybdenum and various base metals. There is, however, no direct evidence to prove that these layers are in fact alloys of molybdenum and the base metal. Normal methods of chemical analysis, even in their most refined form, are quite incapable of determining the compositions of layers of the order of 1$\mu$ in thickness. The opportunity arose, however, to have the layer formed between molybdenum and a steel base analysed by a technique only recently developed, that of X-ray microanalysis.

X-ray microanalysis, evolved originally by Castaing[5] has been developed in modified form by Dr. V. E. Cosslett and Dr. P. Duncumb[6] of the Cavendish Laboratory, Cambridge. An instrument based on the design of Cosslett and Duncumb has been built at the T.I. Research Laboratories, Hinxton Hall, by Dr. D. A. Melford in collaboration with Dr. P. Duncumb. It was on this latter machine that the layer between a mild steel base and a sprayed molybdenum deposit was analysed.

The technique of X-ray microanalysis consists essentially of irradiating the surface under examination with a fine focus electron beam and analysing the resultant X-ray emission. By this means it is possible to determine the composition of the metal at the surface of the specimen ; the metal-sample analysed is approximately 1 $\mu$ in diameter and hemispherical in shape. The instrument developed by Cosslett and Duncumb permits the electron

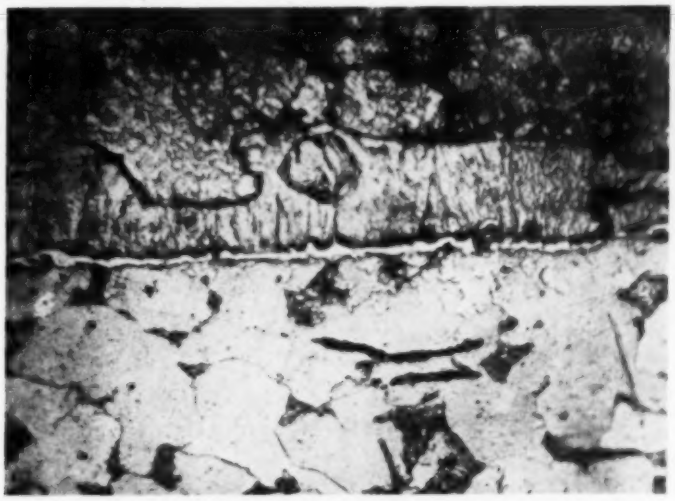


Fig. 2.—Optical micrograph showing sprayed molybdenum on chemically polished mild steel. Etching reagents: molybdenum—alkaline ferricyanide; mild steel—nital. × 920

Fig. 3.—Optical micrograph showing sprayed molybdenum on cobalt. Etching reagents: molybdenum—alkaline ferricyanide; cobalt—aqueous acidic ferric chloride. × 920

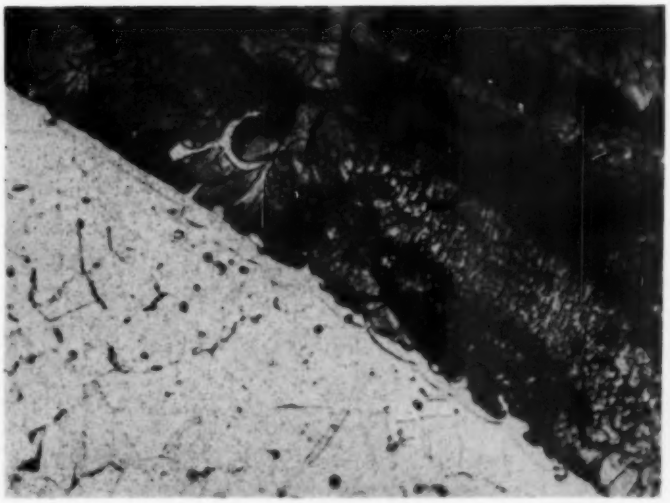


Fig. 4.—Optical micrograph showing sprayed molybdenum on Brightray. Etching reagents: molybdenum—alkaline ferricyanide; Brightray—acid ferric chloride. × 920

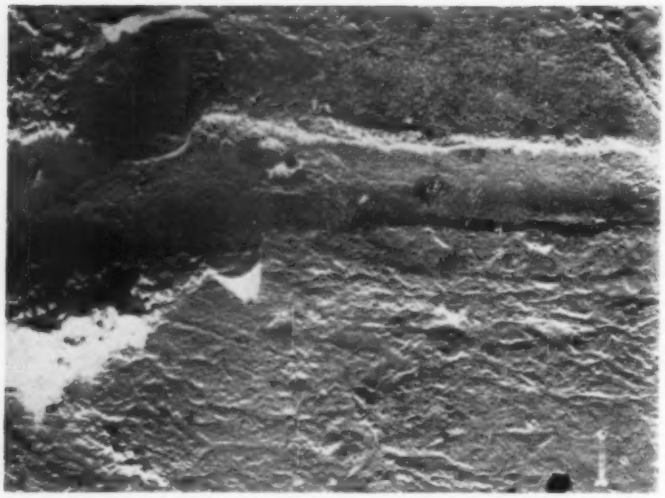


Fig. 5.—Electron micrograph showing sprayed molybdenum on mild steel. × 7,500 approx.

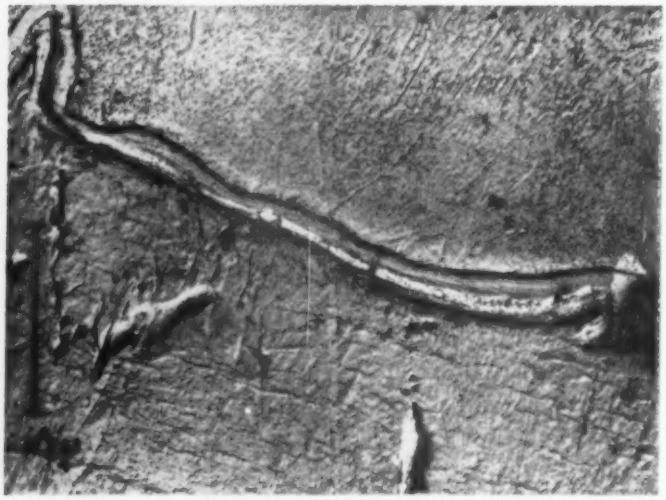


Fig. 6.—Electron micrograph showing sprayed molybdenum on cobalt. × 3,000 approx.

Fig. 7.—Electron micrograph showing sprayed molybdenum on cobalt. × 12,000 approx.

**Fig. 8.—Electron micrograph showing sprayed molybdenum on Brightray. × 7,500 approx.**

**Fig. 9.—Electron micrograph showing outgrowth from molybdenum/mild steel interfacial layer extending into the molybdenum. The interfacial region is on the left. × 7,500 approx.**

**Fig. 10.—Electron micrograph showing outgrowths from molybdenum/Brightray interfacial layer extending into the molybdenum. The interfacial layer is seen on the left. × 9,000 approx.**

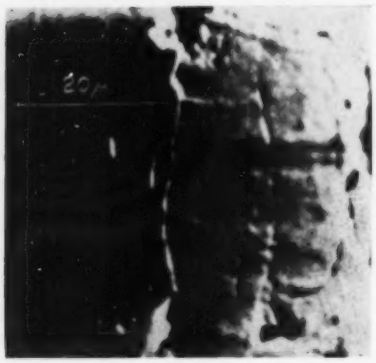


**Fig. 11.—Electron image of sprayed molybdenum/mild steel interface. × 1,200**

beam to scan an area of approximately $\frac{1}{2}$ mm. square. The X-ray emission is collected by a counter, the output of which modulates the brightness of a beam scanning an oscilloscope in synchronisation with the electron beam. Using a crystal spectrometer, it is possible to select one X-ray line and to collect only the emission of this line. The oscilloscope image formed is therefore one in which the brightness at a given point on the oscilloscope screen is proportional to the amount of the emitting element present at the corresponding point in the surface of the specimen. Additionally, the high energy scattered electrons can be collected, using a scintillation counter and an image displayed on another oscilloscope. This is essentially a reflection electron microscope picture. When required, the electron probe can be positioned at any point on the electron image and an analysis obtained by recording the emission intensity from a particular element and comparing it with that of the pure element with the same beam current. It is also possible to make the electron probe track slowly across a sample so that the variation in the amount of a given element along the track can be determined.

In the present work the X-ray microanalyser was required to determine the iron and molybdenum contents of the layer between a sprayed molybdenum deposit and steel base. Fig. 11 shows the electron image obtained from the microanalyser, the magnification being about 1,200 diameters. The two black lines across the photograph are contamination lines made when the electron probe was tracking slowly across the surface of the specimen. Fig. 12 shows the trace produced by tracking the electron beam slowly across the surface between the iron and molybdenum, iron K$\alpha$ radiation being selected. This trace shows, therefore, in a qualitative manner, the distribution of iron across the interface. The high level recorded at the left of the picture represents the steel base. As the electron beam crosses the interfacial layer the iron concentration drops sharply to a small plateau (*A*, Fig. 12) and then as it leaves the interface and moves into the molybdenum the iron content becomes very low. The step in the sharp transition from 100% iron to virtually 0% iron which occurs as the electron beam crosses the interfacial layer, suggests that the layer between the base and the deposit is, in fact, an alloy of molybdenum and iron. Quantitative analysis for iron and molybdenum was carried out at two points in the layer with the electron beam stationary. The first analysis gave 18% Mo–72% Fe and the second 25% Mo–62% Fe. It is probable that the second analysis is the more accurate. Bearing in mind the fact that the layer being analysed is only about 1 $\mu$ in thickness and that the diameter of the electron beam is of much the same order, it is obviously impossible to be completely certain that the quantitative analyses obtained were restricted to the interfacial layer. Considering, however, the evidence obtained by slowly tracking the beam across the interface, together with that from the point analyses, it seems reasonable to conclude that the layer between the deposit and base is an alloy of molybdenum and iron and that it contains approximately 60% iron.

## Discussion

The manner in which sprayed metal adheres to a base has been a subject of discussion and controversy for many years. The general need for the surface of the base to be roughened in some way has led many investigators to hold the view that adhesion arises largely as a result of the deposit being mechanically keyed-in or locked (as a result of surface tension effects)[7] to the base.

On occasion, investigators have noted that high adhesion occurs when metal is sprayed on to a base which is relatively smooth. In such cases it seems doubtful whether a mechanical keying or locking type of mechanism can account for the degree of adhesion obtained. As an alternative, it has been suggested[8] that adhesion arises as a result of the formation of metal/metal junctions between the base and the deposit. This type of adhesion arises essentially as a result of the interaction of atomic forces at the surfaces of the two metals.

Considering the polishing treatments applied to the various metal surfaces prior to spraying, it would seem unlikely that the adhesion noted when iron, cobalt and Brightray bases were used could result from any form of mechanical keying-in or locking as a result of surface tension. Nor does the appearance of a clearly defined layer between the base and deposit suggest that the

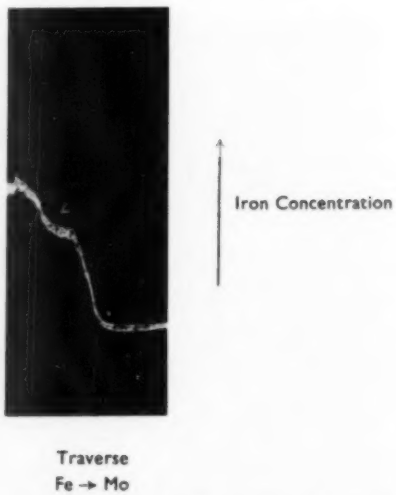


**Fig. 12.—Distribution of iron across the interface.**

adherence observed is a matter of simple atomic interaction between the surfaces of the molten particles and the base metals. It would appear that when molten molybdenum particles come into contact with a base such as iron, fusion of the iron surface occurs. In the case of the iron base, the evidence of the X-ray microanalyser suggests that the fused iron layer alloys with the molybdenum deposit. No evidence is available regarding the constitution of the interfacial layers present between sprayed molybdenum and cobalt and Brightray bases. The presence of an alloy layer between a base and a deposit will give a degree of adhesion which is dependent upon the mechanical properties of the layer.

Molybdenum also appears to have a second mechanism of adhesion which may operate even where the fused surface of the base does not alloy with the deposit. For this second mechanism to function, two conditions must be fulfilled :—

(*a*) the deposit must be able to fuse the basal surface ;

(*b*) infiltration of the fused metal into the porous deposit must not be prevented by surface films, e.g. oxide.

If the basal surface is fused and there is no interference from surface films, the liquid metal will infiltrate into the porous regions of the deposit. This will give rise to a considerable degree of adhesion between base and deposit.

A number of factors will determine whether fusion of the basal surface occurs when the molybdenum deposit is applied. First, there is the melting point of the base ; the higher the melting point of the base the smaller is the chance of a discernible fused layer being formed. Again, the higher the conductivity of the base the thinner will be the surface zone of the base which will reach the melting point. Finally, oxide films on the surfaces of the base or deposit particles may interfere with heat transfer. In the case of the iron, cobalt and Brightray bases, it may be concluded that the various factors noted above were favourable to fusion occurring whilst in the case of chromium they were unfavourable. This is not unexpected, since the melting point of chromium is some 350° C. higher than that of iron and it has an adherent oxide film which may well interfere with heat transfer.

## Conclusions

(1) Interfacial layers are formed between sprayed molybdenum and mild steel, cobalt and Brightray bases.

(2) The layer between steel and sprayed molybdenum appears to be an alloy of molybdenum and iron. Although no analytical evidence is available, it seems likely that the interfacial layers between a molybdenum deposit and cobalt and Brightray bases are also alloys.

(3) The formation of an alloy layer between sprayed molybdenum and steel is probably responsible for the high degree of adhesion of molybdenum to a smooth steel base.

(4) A liquid zone, either alloy or just fused base, is formed between the molybdenum deposit and the steel, cobalt and Brightray bases. The infiltration of this liquid into the deposit gives a second mechanism of adhesion.

## Acknowledgment

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REFERENCES

1 Vanderpool, H. and Shepard, A. P. "Metallizing," 1954, American Society for Metals, Chapter 10.
2 Birchon, D. *Metallurgia*, 1958, **58**, 273.
3 Marshall, W. A. *J. Electrodepositors Tech. Soc.*, 1952, **28**, 127.
4 Bradley, D. E. *Brit. J. App. Phys.*, 1954, **5**, 96.
5 Castaing, R. Thesis, Paris, 1951.
6 Cosslett, V. E. and Duncumb, P. *Nature*, 1956, **177**, 1,172.
7 Ballard, W. E. *Proc. Phys. Soc.*, 1945, **57** (2), 67.
8 Hoar, T. P. *Metal Finishing Journal*, 1959, **5**, 303.

# News in Brief

As part of its continuing efforts to develop new markets, Aluminium, Ltd., is collaborating with Portugese canning interests to build and operate a plant in Portugal to produce aluminium fish cans. Use of such cans, particularly for sardine-type packs, has been pioneered by Aluminium, Ltd.'s, affiliates in Norway over many years. Practically all Norwegian exports of kippered herring and most sardines are now packed in aluminium. Initially, the new canning plant will use specially anodised and lacquer-sealed aluminium strip produced by Aluminium, Ltd.'s, affiliates in Norway or England.

Royce Electric Furnaces, Ltd. have received orders from Associated Transistors, Ltd., for nine furnaces to be installed in the modern transistor factory being erected at Basingstoke. They will have an easy-to-clean streamlined appearance, and will be controlled by proportional, stepless indicating controllers acting through magnetic amplifiers and saturable core reactors.

As a result of the operation of the pit-type Carbodrip gas carburising furnaces supplied by Wild-Barfield Electric Furnaces, Ltd., in fulfilment of an order from the East Indian Produce Co., Ltd., an order was received for an additional furnace of identical capacity which has since been installed. Wild-Barfield have now received a further order for larger furnaces, in this case having working dimensions nominally 36 in. diameter × 54 in. deep.

Orders for two ore-handling plants, worth a total of £1½ million, have recently been received by The General Electric Co., Ltd. One of these plants, valued at £1 million, is for installation at the Scunthorpe South Works of the Appleby-Frodingham Steel Co. The other is for the Ravenscraig Works of Colvilles, Ltd., and this brings the total value of orders received by G.E.C. for the Ravenscraig Works during 1960 to £2½ million.

As a result of an agreement concluded between Tool Treatments (Chemicals), Ltd., of West Bromwich, and the Chemical Corporation of Massachusetts, U.S.A., the Blakodize process, the chemical black on steel finish produced by Tool Treatments, will be marketed under licence in America by the Chemical Corporation, and The Luster-on products of the Chemical Corporation, a leading company in America on chromate conversion treatments, will now be marketed in this country by the West Bromwich firm.

H. & E. Lintott, Ltd., of Horsham, electro-mechanical engineers specialising in a wide variety of high-quality, light and heavy precision manufacture for the nuclear and general engineering industries, have changed their name to Lintott Engineering Ltd.

# Copper and Copper Alloys

## A Survey of Technical Progress During 1960

Compiled by the Staff of the Copper Development Association

*This survey is a summary of current developments in the field of copper and copper alloys over the past year. Aspects covered include extraction, fabrication, finishing, properties and testing. Review articles are, in general, excluded.*

FOR many years *Metallurgia* has featured annually a survey of the literature in the field of copper and copper alloys, and for almost as many years the surveys were contributed by the late Dr. E. Voce, senior metallurgist to the Copper Development Association. When Dr. Voce died last October, his former colleagues at the C.D.A. stepped into the breach and collaborated in the compilation of the present review on similar lines to those of previous years.

### Extraction and Refining

*Flotation*

Molybdenum, which is frequently a troublesome impurity in copper ores, can now be removed by direct flotation of the molybdenite, $MoS_2$, from finely-ground copper sulphide concentrates; a suitable treatment has been described using sodium cyanide and ferrocyanide as copper depressants with sulphuric acid to modify the *p*H.[1] Thus the more complex heat treatment, steaming, or roasting processes which are normally required for removal of molybdenum may be avoided.

*Smelting*

Heat requirements in the smelting of copper matte are predictable from the weights of the products arising from the charge and their respective heat contents. A paper has been published describing the means whereby this can be achieved,[2] and it should be of considerable value in respect of economic problems associated with the process. The difficulties of treating copper-nickel ores have now been largely overcome by the current process used by the International Nickel Co. at Copper Cliff, Ontario. The development of this process, involving flotation of a finely-ground copper-nickel matte with subsequent production of blister copper, has been described.[3]

Some of the important factors affecting copper reverberatory furnace performance have been discussed[4] as a result of experience gained largely at Mufulira Copper Mines, Ltd. Lowering the moisture content in the concentrate is shown to be an advantage, and it is also pointed out that efficiency is reduced when chalcopyrite is smelted as compared with bornite or chalcocite. The proposals are substantiated by a statistical examination of the influence of the various factors concerned.

*Refining*

Two papers[5,6] describe in considerable detail electrolytic refining plant and practice, the authors dealing respectively with well-known copper refineries in America and Northern Rhodesia. A more specific aspect of the subject is dealt with in a patent[7] covering the addition of an acrylamide polymer hydrolyte to the acid copper electrolyte; a more satisfactory copper deposit is claimed to be obtained under these conditions. In the field of fire refining it is worthy of mention that natural gas is being used in place of poling in the standard refining cycle.[8]

*Slag Treatment*

Selective smelting of iron-bearing copper slags by the Strategic-Udy process is to be commenced in the near future. A description of this[9] states that the slag is melted with coal, lime and a reducing agent at about 2,600° F. (1,425° C.) to volatilise most of the zinc, while the copper separates as matte leaving a copper-free iron-bearing slag.

*Zone Refining*

A book[10] has been published covering all aspects of this interesting process, while from another source[11] comes news of a special apparatus enabling a bar of copper to be refined with great simplicity; a molten zone is formed and maintained of constant width while being made to travel along the bar.

### Foundry Practice

*New Processes*

In the new Asarco copper plant at Perth Amboy, the refining cycle before casting is no longer used; tough-pitch copper prepared from thermally-pretreated cathodes is continuously tapped from arc melting furnaces to feed a wirebar casting wheel as well as a continuous casting machine for cakes and billets. The processes involved have been fully described.[12]

A new founding method known as "compression casting," said to be applicable to copper alloys, has been developed in Russia;[13] molten metal is poured between two dies, one of which is movable, after which the dies are brought together to fill the cavity. Further compression is applied to the metal as it solidifies, so enabling very thin sections to be cast in larger components than may be made by conventional pressing techniques. A comparable process[14] is "pressure casting," which enables very close tolerances to be attained; it is advocated for precision-cast parts in beryllium copper, including moulds for the plastics industry. A new procedure[15] for casting complex components such as bronze statues has been developed involving the use of a foamed polystyrene pattern. After moulding, the metal may be poured directly, since the pattern vaporises when brought into contact with the molten metal.

Following the successful dispersion hardening of copper by powder metallurgical means, experiments have been carried out to investigate whether a dispersed material could be introduced into molten copper before casting in order to give similar properties. The addition of fine powders has been considered by Williams *et al.*[16] who found that molybdenum shows the most promise in this respect. Four procedures for producing hardening from an oxide dispersion by reaction in molten copper have also been investigated by these workers[17] and promising results were obtained with nickel and titanium additions.

*Gunmetals*

Much interest has been shown recently in the optimum composition of gunmetals for various purposes, mainly as a result of work by the British Non-Ferrous Metals Research Association and the International Nickel Co. (Mond), Ltd. Patton[18] has reported a further study on nickel-bearing gunmetal, confirming that its principal advantages are less sensitivity to variation in mechanical properties with section thickness and greater ease in making pressure-tight castings. Lead content is also an important factor in achieving pressure tightness and experiments originating from Sweden have been described,[19] from which a theory for the advantageous effect of lead in this respect is discussed. Stolarczyk and co-authors[20] have examined the influence of bismuth, iron, arsenic and antimony on the properties and foundry characteristics of 88/10/2 and 85/5/5/5 gunmetals. The results are discussed in the light of the current draft revision of B.S.1400.

*Aluminium Bronze*

Two general papers[21, 22] on the debatable subject of melting and casting of aluminium bronze provide much detail which should be of value to the practical foundryman. Longden[23] has described the production of a large aluminium-bronze propeller giving details of pouring, gating and feeding methods. An investigation[24] has been made on the respective castability and mechanical properties of high-manganese nickel-aluminium bronze, ordinary nickel-aluminium bronze, and high-tensile brass for propeller castings; it was concluded that the high-manganese alloy had the most favourable foundry characteristics.

*Tests and Test Bars*

A new fluidity test mould has been described[25] and used to study the effect of superheat and impurities on the fluidity of certain alloys, including 60/40 brass with varying aluminium contents. It has also been suggested[26] that the test may be used to indicate the oxygen content in copper alloys. A modified melt-quality test[27] enables the gas content of aluminium bronze to be checked in the foundry within five minutes, and if the test is varied slightly, it may also be applied successfully to gunmetals and phosphor bronzes.

A series of laboratory tests aimed at selecting a test bar giving consistently-high tensile properties in 85/5/5/5 gunmetal has been reported by Reiter[28]; the recommended test bar has been used in fourteen different foundries and a marked improvement has been obtained. The possibility of using shell-moulded test bars for tin bronzes has also been investigated by other workers,[29] and the results compared with those obtained from sand-moulded test bars.

*Impregnation*

Some of the particular problems in selecting suitable impregnants for castings in various fields of application and the methods used for copper-base alloys have been discussed in papers by Fabian[30] and Behen.[31] Polyester-styrene impregnants containing special stabilisers are recommended in one case, while in the other, sodium silicate with powdered copper, iron or clay is suggested.

*Grain Refining*

Various methods of effecting satisfactory grain refinement in cast copper have been investigated and the mechanical properties of the resulting castings were determined[32]; of a large number of additions, only lithium and bismuth were found to have any significant effect. In a general review of the significance of grain structure in sand castings, Kondic[33] has dealt with grain refinement of brasses and copper-aluminium alloys.

*Properties of Shell-Moulded Copper Alloys*

In an assessment of the properties of shell-moulded aluminium bronze and gunmetal by Glick,[34] it has been shown that in the case of aluminium bronze the structure and properties are similar to sand castings, whereas with gunmetal the structure is quite different and the properties may also be influenced. Gunmetals are shown to have an almost wholly equiaxial structure which makes greater attention to feeding necessary, and techniques for obtaining pressure-tight shell-moulded gunmetal castings are suggested.

## Metalworking Techniques

*Annealing Processes*

A new roller-hearth furnace[35] for bright annealing copper tubes is claimed to require the attention of only one operator. Working at 500° C., the furnace, which contains a protective atmosphere derived from propane, is capable of annealing about one ton of tubes per hour.

Edwards[31] has reported on a new continuous "flash" annealing process, whereby metal strip up to 48 in. wide is passed through a heating unit, then quench-cooled and finally re-coiled. The main advantage claimed is that grain size is from one-third to one-fifth of that produced in conventional annealing. Brass strip has been heat treated in this way.

Another new method of continuously annealing metals,[37] including copper and copper alloys, in wire or strip forms, incorporates a system of heated and heat transfer rollers; these are designed to preheat the untreated portion of the strip or wire by transferring heat to it from the annealed metal via the heat-transfer roller. As a result, extension of the metal due to thermal expansion is minimised, and the part of the strip or wire passing over the heated roller maintains close contact with it, thus ensuring complete annealing.

*Cold Working*

Wilcox and Whitton[38] have described the cold extrusion of copper, with lubrication, at a low speed (0·44 in./min.) using different die angles and extrusion ratios. Extrusion pressures calculated from an empirical equation derived in earlier experiments agree with experimental values within ± 7%. This equation has now been shown to be applicable over a wide range of conditions to a number of materials extruded at slow speeds.

Some recent developments in the production of both

helically-convoluted and annularly-convoluted thin-walled tubes, including those made from copper and copper alloys, have been discussed by Poulsen.[39] The author also describes the manufacturing techniques employed in the production of a semi-flexible helically-convoluted tube which can be bent by hand to very small radii.

A liquid lubricant, consisting of an aqueous suspension of magnesium aluminium silicate and a diglycol ester, is claimed to be particularly suitable for deep drawing of nickel silver and fine-grained brass.[40]

*Explosive Forming*

Cook[41] has described recent developments in the underwater explosive forming of metals, whereby sheet may be pressed into moulds by explosive charges detonated in the vicinity of the metal blank. Brass plates were also successfully coined by applying a uniform high pressure (resulting from an explosive charge) to a stencil placed on top of the plate, and the author also reports that abutting lengths of copper tube have been joined by expanding the ends inside a strong metal collar by an explosive charge detonated inside the water-filled tubes.

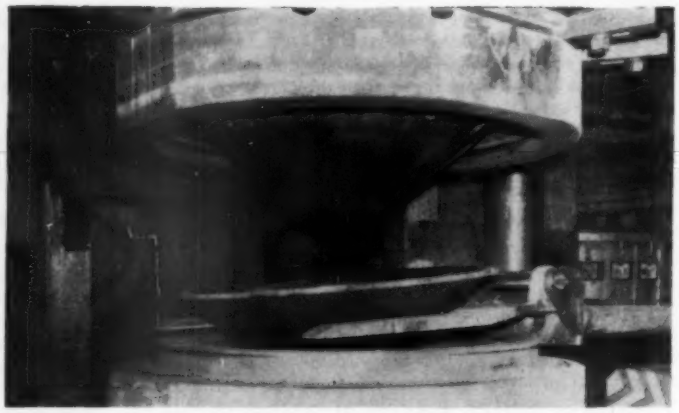
Canadian developments in explosive forming have been revealed by Tardif,[42,43] who states that conical and hemispherical shapes in copper have been formed by a process of "metal gathering." In this method, a blank holder is not employed, thus leaving the metal blank free to be forced downwards towards the bottom of the die, resulting in a thickening of the blank. The same author relates how the welding of dissimilar metals has been achieved by means of explosive pressures, and quotes a figure of 17,000 lb./sq. in. for the shear strength of a stainless steel-brass couple made in this way. According to Savitt,[44] explosive forming techniques have been used in tube forming. He quotes an example of an annealed cartridge-brass tube, the outside diameter of which was increased from 1·002 in. to 1·34 in.

*Finish-Blanking*

Howard[45] has described tests carried out at the Production Engineering Research Association on the use of radiused blanking dies for producing smooth and crack-free sheared edges on copper. Some useful comments on the use and construction of finish-blanking tools for this purpose are made. A detailed description of a Swiss fine-blanking process involving the use of specially-designed tools has been given by Haag.[46] The process is said to be capable of producing metal blanks with a tolerance of 0·0004 in. Piercing of very small holes, of diameter less than one-half the metal thickness, without any risk of breaking the punches on withdrawal, is said to be possible.

*General*

The Battelle Memorial Institute[47] has developed a process of extruding clad-metals, such as aluminium clad to copper or copper alloys. The core material is fed through a hollow mandrel converging upon a die. The mandrel is housed inside a chamber containing rams used to extrude the cladding material, which is forced through openings between the mandrel and the die. The cladding may be produced in a variety of shapes; for instance, a hollow core could be overlaid with clad fins. Another report from the U.S.A.[48] states that the experimental production of light-gauge seamless copper tubing, which can be shipped in ribbon form and then inflated at the point of use, indicates that it will be economical to produce in gauges not at present available.



**A 5ft. diameter closed-die copper forging for the nose cone of an inter-continental ballistic missile.**

Laman[49] has reported on two new Soviet methods of producing fine copper wire from 20 to 2 microns in diameter. In one method molten metal is forced by air or inert-gas pressure through a small orifice. As the stream of molten metal enters the atmosphere, it cools, and wire is formed. The second method involves a drop of molten metal which is held in space within the confines of a glass tube by a high-frequency magnetic field. Heated by high-frequency current, the drop of metal softens the glass, which can then be drawn out into a very fine capillary which is filled by the molten metal. The resulting wire, in its glass sheath, is wound on to a revolving spool.

## Mechanical and Physical Properties

*Fatigue Behaviour*

The hardening of annealed copper during fatigue testing was studied by Siede and Metcalfe.[50] The tests, in which a Baldwin-Sonntag rotating-beam machine was used, showed that the degree of hardening (from 55 to about 75 HV) was independent of the applied stress, and occurred largely during the first 4,000 stress reversals. Furthermore, it was found that copper hardened in this manner is more resistant to annealing and has a higher creep strength than when hardened by other means.

Surface coatings of long-chain polar substances such as dodecyl-alcohol and dodecyl-amine are claimed to increase the fatigue strength of beryllium-copper alloys, and an increase of 250% on the fatigue life of such an alloy, stressed at 50,000 lb./sq. in. is said to have been achieved.[51]

*Young's Modulus*

Work by Thompson and Paré[52] concerns the variations of elastic modulus and internal friction of pure copper

crystals after neutron bombardment at a number of temperatures within the range − 183° to + 27° C. The effects of electron irradiation and subsequent thermal treatment on copper showed that the elastic modulus increased following short exposures to high energy electron irradiation at −190° C.[53] The increase was observed to occur in three distinct stages, at temperatures in the region of − 45°, −5° and + 80° C.

*Precipitation-Hardening Alloys*

Russian investigations[54] aimed at reducing the beryllium content of beryllium copper have resulted in an alloy containing 0·6–1·2% beryllium, 5–12% manganese, and up to 0·2% titanium. These alloys are claimed to have the same strength as normal-beryllium copper, but are said to be more ductile, cheaper to produce and have a higher corrosion resistance.

Smith[55] found that a precipitation-hardenable copper-nickel-tantalum alloy (79/20/1) reaches maximum hardness after ageing at 750° C., and if cold worked prior to ageing, does not recrystallise below this temperature. The alloy is said to possess hot and cold working characteristics similar to those of cupro-nickel, and to have good tensile properties at elevated temperatures.

Tensile-strength properties of copper–6·5% aluminium alloys containing up to 1·4% cobalt have been reported by Dennison.[56] A cobalt content of between 0·5 and 1·0% was found to provide the optimum mechanical properties in this range of age-hardening alloys.

*Elevated-Temperature Properties*

Nachman and Olds[57] report that a cermet made from molten copper containing a thorium boride dispersion, has four times the tensile strength of copper at 1,800° F. (980° C.), and is suitable for the manufacture of certain rocket and missile components as well as for jet and internal-combustion-engine applications. As a result of creep tests carried out on oxygen-free high-conductivity copper under constant stress in a vacuum, Feltham and Meakin[58] found that the creep rate conformed to an equation which the authors have given.

*Low-Temperature Properties*

McClintock and others[59] have described how the tensile properties of oxygen-free high-conductivity copper, normal-beryllium copper, low-beryllium copper, silicon bronze and phosphor bronze have been determined at temperatures within the range − 253° to + 27° C. Tensile strength, yield strength and Young's Modulus in each case generally increased with decrease in temperature, but two departures from this trend were observed. In the case of silicon bronze, the value of Young's Modulus dropped from $21 \times 10^6$ lb./sq. in. to $19 \times 10^6$ lb./sq. in. over the temperature range − 197° to − 253° C. Over the same temperature range, the ductility of phosphor bronze, as measured by percentage elongation, showed a slight decrease. Other interesting contributions have been made by Barron,[60] who found that the thermal conductivity of pure copper at − 253°C. is about thirty-three times that value at room temperature, and by Martin,[61] who has measured the specific heat of copper over the temperature range − 253° to + 27° C.

*(To be continued)*

REFERENCES


1 " Flotation of Molybdenite from Copper," *Brit. Chem. Engng.*, 1959, **4**, Oct., 505. Deco Trefoil, **23**, (No. : 3).
2 Evans, G. L., " Copper Matte Smelting : The Influence of Charge Composition Upon Heat Requirements," *Bull. Inst. Min. Metall.*, 1960 (No. : 639), Feb., 201–209.
3 Sproule, K., Harcourt, G. A., and Renzoni, L. S., " Treatment of Nickel-Copper Matte," *J. Metals*, N.Y., 1960, **12**, Mar., 214–219.
4 Verney, L. R., " Factors Affecting Copper Reverberatory Furnace Performance and Their Influence on the Choice of Various Smelting Methods," *Bull. Inst. Min. Metall.*, 1960 (No. : 639), Feb., 211–236.
5 Mosher, M. A., " Some Practical Aspects of Copper Refining in a Multiple System Tank House," *J. Electrochem. Soc.*, 1960, **107**, Jan., 7C–12C.
6 Lockyer, P. C. and Neller, R. R., " Electrolytic Refining of Copper," *Metal Ind.*, Lond., 1960, **96**, Jan. 29, 88–92 ; Feb. 5, 110–116 ; Feb. 12, 129–130, 134.
7 Lapee, R. J., of the Anaconda Company, " Electrolytic Refining of Copper," Canadian Patent 583,429.
8 Kunell, C. R., " The Development of Modern Copper Smelting," *Trans. Amer. Inst. Min. (Metall.) Engrs.*, 1960, **218**, Aug., 578–584.
9 Burke, J. J., " Udy Process Applied to Copper Slags," *J. Metals*, N.Y., 1959, **11**, Dec., 829.
10 Parr, N. L., " Zone Refining and Allied Techniques," Newnes, London, 1960, 40/–.
11 Tolmie, E. D., " Apparatus for the Zone Refining of Copper," *J. Sci. Instrum.*, 1960, **37**, May, 175–177.
12 Storm, G. D., and Stone, J. R., " New Tough Pitch Continuous Copper Melting and Casting Unit at Asarco's Perth Amboy Plant," *Trans Amer. Inst. Min. (Metall.) Engrs.*, 1960, **218**, Aug., 584–591.
13 Steiger, A. J., " Compression Casting," *Modern Castings*, 1960, **38**, Aug., 34–37.
14 Nicholls, M. A., and Randall, W. F., " The Application of Pressure Cast Beryllium Copper in Plastic Moulds," *Plastics*, 1959, **24**, Sept., 328–330.
15 " Polystyrene Pattern Simplifies Casting of (Bronze) Statuary," *Foundry*, 1960, **88**, May, 290–293.
16 Williams, D. N., Roberts, J. W., and Jaffee, R. I., " Formation of Dispersions in Molten Copper by Mechanical Mixing," *Modern Castings*, 1960, **37**, Mar., 81–85.
17 Williams, D. N., Roberts, J. W., and Jaffee, R. I., " Formation of a Dispersion in Copper by Reaction in the Melt," *Trans. Amer. Inst. Min. (Metall.) Engrs.* 1960, **218**, June 574–575.
18 Patton, A. M., " An Improved Nickel-Containing Gunmetal for the Production of High Quality Castings," *Brit. Foundryman*, 1960, **53**, Feb., 82–87.
19 Ekbom, L., " Influence of Increased Lead Content on Pressure-Tightness of Leaded Gunmetal," *Foundry Tr. J.*, 1960, Sept. 22, 355–361.
20 Stolarczyk, J. E., Hudson, D. A., and Ashbolt, D., " The Influence of Bismuth, Iron, Arsenic and Antimony in Sand-Cast Gunmetals," *Brit. Foundryman*, 1960, **53**, Nov., 482–495.
21 Dick, J. G., " Melting and Casting of Aluminium Bronzes," *Foundry*, 1960, **88**, Apr., 86–90.
22 Brookhouse, F. E., " Aluminium-Bronze Castings," *Brit. Foundryman*, 1960, **53**, July, 313–314.
23 Longden, E., " Some Highlights in the Experience of a Foundryman," *Brit. Foundryman*, 1960, **53**, Aug., 345–362.
24 Bradshaw, G., Kennedy, M. M., and Dorn, S. H., " High Manganese Nickel Aluminium Bronze Casting Characteristics," *Modern Castings*, 1960, **38**, Sept., 67–74.
25 Cooksey, C. J., Kondic, V. and Wilcock, J., " The Casting Fluidity of Some Foundry Alloys," *Brit. Foundryman*, 1959, **52**, Sept., 381–386.
26 Kondic, V., " A New Test for Fluidity," *Foundry*, 1959, **87**, Dec., 79–83.
27 " Non-Ferrous Melt-Quality Tests." Institute of British Foundrymen. Final Report of Sub Committee TS 45 of the Technical Council. *Brit. Foundryman*, 1960, **53**, Mar., 120–128.
28 Reiter, H., " A Sand-Cast Test Bar for 85/5/5/5 Gunmetal," *Brit. Foundryman*, 1960, **53**, Mar., 128–137.
29 Goldspiel, S., Chrzan, E. W., and Foster, M. L., " Shell-Molded Test Bars for Tin Bronze Casting Alloys," *Modern Castings*, 1960, **37**, Mar., 112–125.
30 Fabian, R. J., " Impregnants for Castings," *Mater. in Design Engng.*, 1959, **50**, Oct., 102–106.
31 Behen, C., " Impregnation," Summary of paper to AFS Seminar on ' Salvage and Repair of Copper-Base Castings.' *Foundry*, 1960, **88**, June, 210.
32 Gould, G. C., Form, G. W., and Wallace, J. F., " Grain Refinement of Copper," *Modern Castings*, 1960, **37**, May, 144–155.
33 Kondic, V., " The Origin and Significance of Grain Structure in Sand Castings," *Brit. Foundryman*, 1959, **52**, Dec., 542–549.
34 Glick, W. W., " The Properties of Castings in Shell Moulds," *Brit. Foundryman*, 1960, **53**, Jan., 1–10.
35 Arens, J., " A Modern Roller-Hearth Furnace for Bright-Annealing Copper tubes," *Z. Metallkunde*, 1959, **50**, (10), 565–567.
36 Edwards, J. A., " A New Continuous Annealing Process," *Prod. Finish.*, Lond., 1960, **13**, Oct., 98–99.
37 Aktiebolaget Svenska Metallverken, " A Method and Apparatus for Continuous Annealing Metal Strip or Wire," British Patent 827,217.
38 Wilcox, R. J., and Whitton, P. W., " Further Experiments on the Cold Extrusion of Metals using Lubrication at Slow Speeds," *J. Inst. Metals*, 1959-60, **88**, Dec., 145–149.
39 Poulsen, S. C., " The Production of Convoluted Thin-wall Tubes," *Machinery*, Lond., 1960, **97**, Aug. 3, 248–257.
40 Hartman, L. F., of Olin Mathieson Chemical Corporation, " Metal Working," Canadian Patent 584,276.
41 Cook, J. H., " Working Metals By Detonating Explosives," *Sheet Metal Ind.*, 1960, **37**, Apr., 253–258.
42 Tardif, H. P., " Explosive Forming in Canada," *Metal Prog.*, 1960, **77**, Jan., 128–130.
43 Tardif H. P., " High-Energy Rate Forming of Metals," *Canad. Metalwkg.*, 1960, **23**, Apr., 24–28, 53.
44 Savitt, J., " Tube Forming With and Without Dies," *Metalwkg. Prod.*, 1959, **103**, Oct., 30, 1736–1738.
45 Howard, F., " Finish Blanking," *Sheet Met. Ind.*, 1960, **37**, May, 339–351, 354 ; discussion 355–356, 374.
46 Haag, R., " Finish Blanking," *Sheet Metal Ind.*, 1960, **37**, May, 352–354 ; discussion 355–356, 374.
47 " Extrusion Cladding " *Mech. Engng.*, N.Y., 1960, **82**, June, 78–79.
48 " Tube to be Shipped Flat," *Plumber*, 1959, **81**, Oct., 29.
49 Laman, N., " Two Kilometres of Wire from a Drop of Metal," *Eastern Metal Rev.*, 1960, **13**, Aug. 8, 739–740.
50 Siede, A., and Metcalfe, A. G., " The Fatigue Hardening of Copper," *Trans. Amer. Inst. Min. (Metall.), Engrs.*, 1959, **215**, Dec., 947–949.
51 " Organic Coatings Lessen Metal Fatigue," *Engineering*, Lond., 1960, **190**, July 1, 2.

52 Thompson, D. O., and Paré, V. K., "Effect of Fast Neutron Bombardment at Various Temperatures upon the Young's Modulus and Internal Friction of Copper," *J. Appl. Physics.*, 1960, **31**, Mar., 528–535.
53 Soain, A., and Bienvenue, L. L., "Effects of Electron Irradiation and Subsequent Thermal Treatment on Young's Modulus of Copper," *J. Appl. Physics.*, 1960, **31**, Feb., 249–252.
54 "New Copper-Based Alloys," *The Guardian*, 1960, July 26, 14.
55 Smith, C. S., "Alloys of Copper, Nickel, and Tantalum," *Trans. Amer. Inst. Min. (Metall.) Engrs.*, 1959, **215**, Dec., 905–909.
56 Dennison, J. P., "Mechanical Properties Obtainable by Precipitation-Hardening Treatments in a Range of Copper-Aluminium-Cobalt Alloys," *Metallurgia*, Manchr., 1959, **60**, Oct., 129–132.
57 Nachman, J. F., and Olds, L. E., "Alloys of Unusually High Temperature Strength Produced by Uniform Dispersion of Ceramic Particles in Matrix," *Industr. Heating.*, 1959, **26**, June, 1214–1216.
58 Feltham, P., and Meakin, J. D., "Creep in Face-Centred Cubic Metals with Special Reference to Copper," *Acta Metallurgica*, 1959, **7**, Sept., 614–627.
59 McClintock, R. M., Van Gundy, D. A., and Kropschot, R. H., "Low-Temperature Tensile Properties of Copper and Four Bronzes," *Bull, Amer. Soc. Test. Mater.*, 1959, No. 240, Sept., 47–50.
60 Barron, R. F., "Low-Temperature Properties of Engineering Materials," *Mach. Design*, 1960, **32**, Mar. 17, 189–195.
61 Martin, D. L., "The Specific Heat of Copper from 20° to 300° C.," *Canad. J. Physics*, 1960, **38**, Jan., 17–24.

# Arc Furnaces for Steel, Peech & Tozer

## Further Units Ordered from G.W.B. Furnaces Ltd.

ORDERS have now been received by G.W.B. Furnaces, Ltd., to build four giant electric arc melting furnaces as part of Steel, Peech & Tozer's £10 million development programme. The total order is the largest of its kind in the world. A year ago G.W.B. were awarded a contract from Steel, Peech & Tozer to build two of these electric arc melting furnaces which will be almost twice as large as any previously built in Great Britain: the company has now received an extension to this order. The steel construction will be carried out by The United Steel Companies' own subsidiary company, Distington Engineering Co., Ltd. Each furnace has an electrical rating of 40,000 kVA., and the total output of the finished plant will be 1,135,000 ingot tons of steel a year.

The furnaces are entirely British built and engineered, the basic mechanical design being that of Demag-Elektrometallurgie. They have a nominal capacity of 150 tons, but they will be worked with a 110 ton charge in order to have a shallow bath, with a large surface area; this technique is considered by some metallurgists as a better way of making steel, rather than having a deep bath and smaller surface area for a given tonnage capacity.

### Mechanical Design Features

The weight of the electrode supporting structure is permanently carried by the gantry which, after raising the roof, swings aside to allow charging of the furnace. Roof raising is by means of a hydraulic cylinder, the gantry being swung aside by an A.C. motor through a train of gears. The shell and gantry are mounted on a steel platform, the whole of which is supported by three arc shaped rockers which allow the furnace to tilt forward 45° for pouring and backward 15° for slagging. The drive for tilting the furnace is by two D.C. motors through gear trains to pendant pin racks attached to the underside of the furnace. The control of tilting is through Ward Leonard sets.

The shell is arranged for rotation which allows drilling of the scrap if so desired in three positions for each electrode. Rotation is 40° either side of the normal electrode position. The advantage of being able to reposition the shell in respect of each of the three electrodes allows for more even wearing of the shell lining and so increases the tonnage output for each lining. Rotation of the shell is by means of an A.C. motor through a train of gears.

These furnaces will be installed having the interleaved heavy current connections made from the transformer outgoing terminals to the point where the delta connection is made at the electrode clamps. Water cooled flexible cables are employed to carry the heavy phase currents from the transformer to the water cooled bus tubes carried by the electrode arms. To obtain maximum interleaving and balancing of electrode currents in each phase, four-electrode mast construction is employed. The two outer masts carry electrode arms which support the outer electrode, the arm movements being synchronised with each other. Balancing of the three electrode currents ensures even wearing of the shell refractory and greater stabilisation of the three arc currents, and reduces the reactive MVA. swing presented to the electricity supply system. The effect of interleaving the heavy current connection also reduces the percentage voltage reactance, so improving the power factor.

### Electrode Positioning

Single acting, ram-type, cylinders are used for positioning the electrodes, and counter-balancing is provided by arranging the exhaust from the cylinders to be at a positive pressure. The regulator employed for controlling the electrode position is of the true impedence type, a specially developed moving coil actuated valve being employed. The windings of this special moving coil assembly have a high rate of response and sensitivity, and as the hydraulic control valve is subject to oil pressure at each end of its operating piston it will come to rest when the two pressures are equal. This arrangement eliminates any possible variation in calibration due to variation in oil pressure or viscosity.

To ensure stable arc conditions, which are necessary to achieve the highest possible working power factor, electrical efficiency and minimum kWh./ton to melt the steel, the mechanical construction of the furnace platform gantry and electrode-supporting mast structure have been designed to enable the use of the high speed, high rate of response, hydraulic electrode control regulator. Interleaving the heavy current connections, and so reducing the reactance of this circuit, makes it essential to employ high speed electrode control in order to achieve a high working power factor during the breakdown period of the melt.

Power for each furnace will be derived from a 40 MVA. transformer specially designed for its duty and employing on-load resistor bridging type tap changing equipment. The transformer consists of two basic units, a tapped auto feeding, and a double wound straight ratio unit. The heavy current terminations will be made by bringing out a number of connections in parallel and interleaved for each of the three phases, connections being brought out from the windings through the side of the transformer tank. Transformers will employ forced oil cooling through an externally mounted water cooled heat exchanger. The primary winding will be suitable for connection to a 33,000 volt, 3 phase, 50 cycle supply and the maximum arc voltage will be 565 volts.

# Spark Erosion Machining Equipment

## New Range Introduced to British Industry

IN contrast to classical machining methods, which involve cutting processes of one kind or another, spark erosion machining removes unwanted metal by micro-explosive means through closely controlled spark discharges. The technique is particularly suitable for machining materials which, because of their hardness or toughness, may be excessively difficult to machine by conventional methods. It can also be used on intractable materials such as Stellite, tungsten-carbide and magnet steel, to produce openings and cavities which might be quite impossible to form by ordinary machining methods. There is no mechanical contact between electrode and workpiece, and this enables holes of any size or shape to be pierced in thin and/or delicate materials which would be deformed by the pressure of normal cutting tools.

The forming of irregular openings in forging, blanking and extrusion dies also comes within the scope of spark erosion machining and the common practice of assembling numerous precision-ground pieces in order to form an irregular cavity in a die can be eliminated in favour of the one-piece homogeneous die. In the mass production of forging dies, as required in the motor industry for example, spark erosion is claimed as the most economical manufacturing method, not least because it yields consistent accuracy in new sets of dies.

### Mode of Operation

The essence of spark erosion is the production of a spark discharge between the workpiece (anode) and a suitably shaped electrode (cathode) immersed in a suitable liquid dielectric and separated by a small gap. A spark is generated when the potential difference across the gap is raised sufficiently to break down the resistance of the dielectric medium so that an electrically conductive path is created. The high current density in the small cross-sectional area of the spark produces spark temperatures of up to 13,000° C. The energy is concentrated on the terminal areas of the spark path and although there is insufficient time for the localised heating to penetrate into the metal, the heating is sufficient to melt and evaporate the metallic particles in these areas and this, together with the powerful shock waves generated, produces a localised micro-explosion which blasts material from the work surface and leaves a characteristic crater.

Crater size, and thus surface finish, is dependent upon the energy passed between electrode and workpiece. The lower the potential difference across the gap, the smaller the crater produced: the quality of finish can thus be adjusted by altering the discharge value across the gap. The spark always occurs at the point where the gap between electrode and workpiece is shortest, and so wanders randomly over the area of erosion, continuously reducing the successive high spots. The erosion at the electrode amounts to about 10–15% of that at the workpiece, depending on electrode characteristics and the erosion rate.

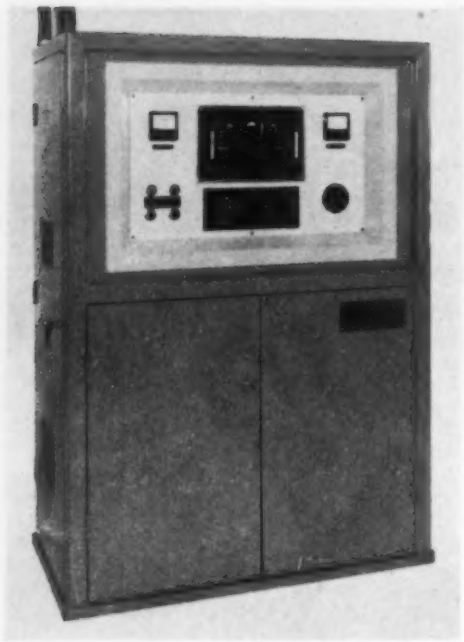
**The Seleromat A spark erosion machine.**

After the condenser has discharged across the gap and the dielectric surrounding the spark path has become de-ionised, the condenser re-charges and its voltage again rises to that of the break-down voltage within the next gap, upon which it once more discharges, and so on. The frequency of sparking is a function of the condenser capacity in microfarads and the frequency of the full wave rectified output of the single phase alternator. Mechanical flushing away of debris is achieved by the explosive effect of the spark discharge, by vibration of the electrode, and by high-pressure feeding of the dielectric fluid past the electrode.

### Languepin Range

As the result of an agreement between La Soudure Electrique Languepin, of Paris, and a new Anglo-French company, Solar Weld Languepin, Ltd., Fulledge Works, Burnley, Lancs., the spark erosion machines developed and produced by the Paris company are now available to industry in the United Kingdom and the Commonwealth. The three machines in the range—the Seleromat A, the Seleromat B, and the Seleromic—all incorporate the unique Languepin design feature of auto-elevation/retraction of the dielectric tank, thus obviating the need to fill and empty the tank.

A complete spark erosion machine installation comprises: (*a*) the machine itself; (*b*) the spark generator,



**The UE 2500 2M spark generator unit with integral control panel.**

housed in a separate cabinet and connected to the erosion head by a screened co-axial cable; and (*c*) a filtration unit for removing micro-solids from the dielectric fluid.

*Spark Generator*

The generator unit for common use with Seleromat A and B spark erosion machines is designated UE 2500 2M. Power is derived from a 3-phase, 440 V., 50 c./s. A.C. supply, and interference suppressors are fitted to each mains cable. Within the generator, A.C. is obtained from a single-phase alternator, the output voltage of which is tuned to a predetermined value and fed into a bridge rectifier circuit. Positive pulses from the rectifier bridge are used to charge one of four banks of capacitors which discharge between the electrode and the workpiece. The full wave bridge rectifier has a "warm-up" delay switch.

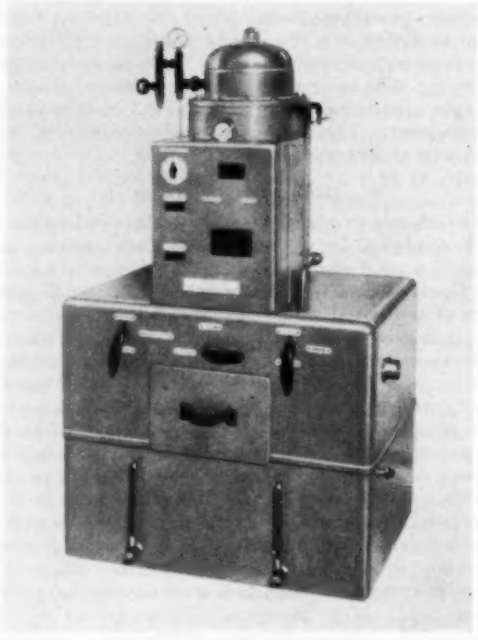
Housed in the cabinet is a push-pull servo amplifier for maintaining a constant spark gap between electrode and workpiece. The amplifier controls the split-field D.C. motor in the erosion head of the machine. The voltage across the spark gap is integrated and compared with a reference voltage and the error is amplified and fed directly to the servo motor to make the necessary corrections to the gap width. The servo control amplifier is housed in a removable drawer mounted on the front of the generator cabinet. The drawer carries indicator lights showing that the alternator excitation circuit is functioning.

The rate of erosion is selected by means of a four-position heavy-duty switch, the control handle of which is situated at the front of the cabinet: the settings are marked "roughing," "semi-roughing," "finishing" and "super-finishing." A small pilot switch working in conjunction with the heavy-duty switch open-circuits the D.C. excitation supply to the alternator field and therefore allows the range to be changed without touching any other controls. A further feature allows control of the D.C. field excitation of the alternator, thus providing a continuous control of the erosion rate over the entire operating range.

Stops can be set to stop the movement of the servohead automatically at any predetermined depth of penetration without switching off the complete generator equipment. Alternatively, the controls can be set to switch off the whole installation at a predetermined depth. The equipment can thus be left running without attention for considerable lengths of time. Current is switched off automatically if the generator cabinet door is opened and if the level of the dielectric is insufficient to submerse electrode and workpiece.

*Dielectric Filter*

The high rates of metal removal by the Seleromat A and B machines require a copious supply of clean dielectric fluid to ensure good surface finish on the work. Mechanical filtration of the fluid at the rate of 11 gal./hr. is obtained from the filtration unit, which will remove particles down to 1 micron in size. It comprises nineteen cylindrical elements built up from paper discs, the fluid entering the elements from the exterior and depositing its solids on the edges of the packed discs. The accumulation of solid particles is removed by blowing air through the element from the centre outward, at a pressure of 30 lb./sq. in. Alternatively a standard cylinder of nitrogen delivering at 30 lb./sq. in. will last approximately six months for this purpose. The filter packs need renewal about every twelve months. On single



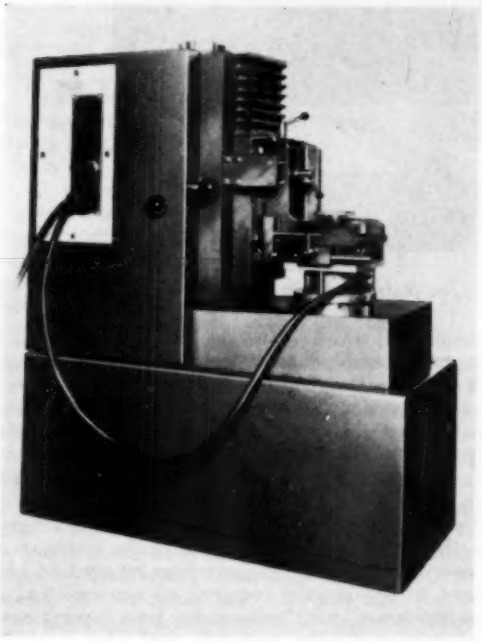
**The dielectric oil filter unit for use with Seleromat A and B machines.**

shift working, element cleaning is only necessary twice per working week. The unit incorporates two pumps, one for scavenging from the erosion machine and the other for returning clean dielectric to the work-table.

*Spark Erosion Machines*

The Seleromat A machine is specially designed for the production of heavy dies, and has a work table measuring 20 in. × 25 in. and capable of supporting a weight of 1 ton. The welded steel base incorporates the supports for the work table and houses the 100 gal. dielectric tank and its pump. The tank is raised and lowered electrically, and the level is automatically maintained so that the work table, the workpiece and the electrode are submersed.

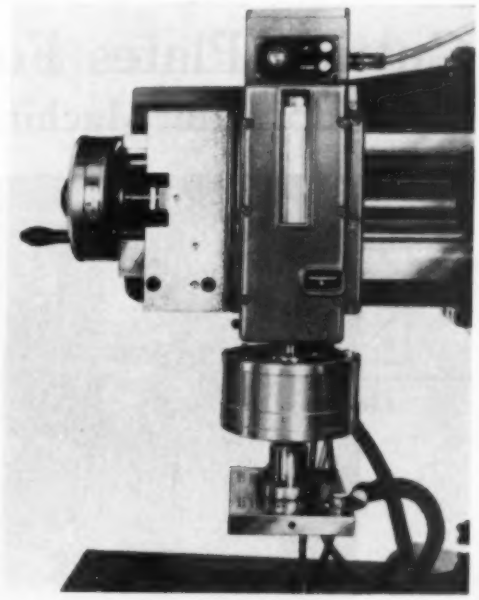
The electrode carrier and its servohead comprise an integral unit at the outer end of an arm which slides



**The Seloromic bench spark erosion machine, showing the dielectric tank in the fully raised position.**

vertically and swings horizontally on a ground pillar rising from the base of the machine at the rear. The arm can be swung clear of the table to facilitate loading of the workpiece. Vertical movement is controlled by a worm driven telescopic screw and fine horizontal adjustment is made by a simple screw device : quick-acting clamps secure the arm in position.

The servohead is carried in opposed V-slides and has a vertical travel of 4 in. Motion is derived from a split-field D.C. motor driving a lead screw through a reduction gearbox, manual control being by push-buttons on the front of the unit. Automatic downfeed is governed by electrical trips and the depth required can be preset to a micrometer scale to increments of 0·001 in. The electrode carrier at the base of the servohead is electrically insulated, and a vibrator can be interposed which,



**The erosion head and electrode carrier of the Seleromat B machine.**

of 50 c./s. provides a mechanical pulsation to assist in flushing eroded debris from the discharge area.

As stated above there are four settings—roughing, semi-roughing, finishing, and super-finishing—and an indication of the capacity of the machine is given in the following table :

| *Setting* | *Erosion Rate* (cu. mm./ min.) | *Surface Finish* (micron) | *Tolerance* (in.) |
|---|---|---|---|
| Roughing | 1,000 | 50 | 0·004 |
| Semi-Roughing | 140 | 18 | 0·003 |
| Finishing | 9 | 5 | 0·001 |
| Super-Finishing | 2 | 2 | 0·0003 |

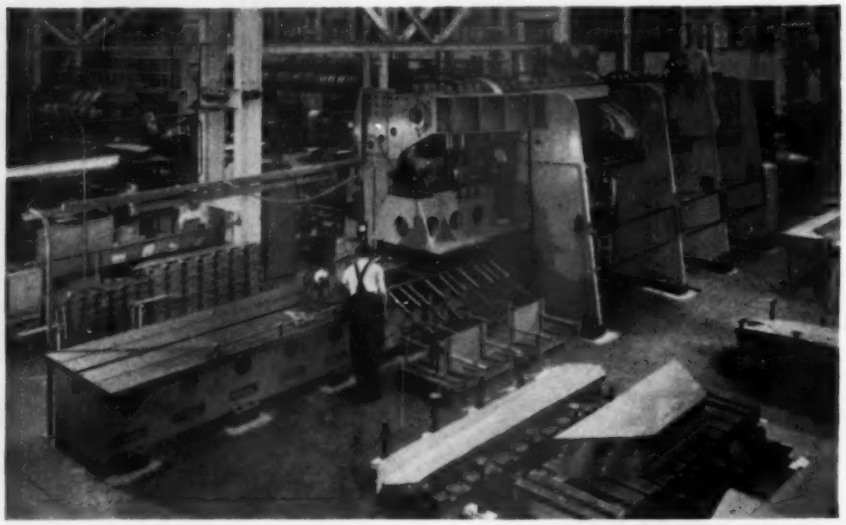
having a vertical movement of 0·0005 in. at a frequency These results were achieved on steel heat treated to Rockwell C 56, using the UE 2,500 2M generator and a 2¾ in. diameter copper electrode.

The Seleromat B machine is similar to the Seleromat A, but the erosion head is mounted on precision co-ordinate slides, for accurate positioning of the electrode over the workpiece, and can be traversed 12 in. longitudinally and 9 in. transversely, by means of screws fitted with micrometer drums calibrated in 0·001 in. (or 0·01 mm.) graduations. Illuminated optical vernier equipment is also available for attaining the highest order of setting accuracy. The electrode carrier and servohead are the same as for the Seleromat A, and the capacity figures tabulated above are also applicable to the B machine.

The Seleromic is the smallest of the three machines in the range and is intended for bench-mounting. It possesses a number of refinements not usually available in machines of like size.

# Cutting Plates For Transformer Cores

## Automatic Machine Installed by Ferranti



**General view of the new fully automatic core plate cutting machine.**

A NEW and unique fully automatic core plate cutting machine has recently been installed in the Transformer Department of Ferranti, Ltd., Hollinwood, Lancs. The research work which has been undertaken over a period of several years into the properties and characteristics of cold rolled grain oriented steels has resulted in the evolution of new core designs which, in turn, require extremely accurate manufacturing techniques. The new core plate cutting machine produces core laminations from continuous rolls of steel to a degree of accuracy never before achieved.

Until the advent of grain oriented cold rolled continuous steel strip, core production was limited by the size of hot rolled electrical sheet steel which could be supplied by the steel manufacturer, i.e. maximum plate size 9 ft. by 3 ft. With the introduction of cold rolled steel in continuous coils, it soon became apparent that the capacity of machines available would still set a limit on core production. Ferranti, Ltd., therefore, embarked upon a plant development programme with the object of introducing some measure of automation to core plate production, to improve the limits to which core plates could be produced and at the same time overcome difficulties in handling.

### Slitting the Coils

To handle the continuous coils of steel supplied by the manufacturers, special purpose rotary guillotines or slitting machines were developed, and Ferranti, Ltd., installed such a machine in 1955. The purpose of this slitting machine is to reduce the width of the coil of steel to that required for the production of core laminations or plates. The machine (see Fig. 1) consists of a de-coiler (*A*) which allows the coil to unwind and pass through the cutting head (*B*), where it is slit into strips of the required width. From the rotary cutters the material passes to the re-coiler (*C*) where the individual strips are re-wound. This machine can handle coils of up to 3 tons weight and from 3½ in. to 36 in. wide. A maximum of eight strips can be cut at one set-up and strips down to 1½ in. wide can be produced.

The continuous strip, of correct width, as received from the slitting machine was, until the installation of the new core plate cutting machine referred to above, reduced to the lengths required on conventional guillotine machines, with subsequent press operations for the punching of holes and slots and edge grinding to remove burrs caused by the slitting and punching

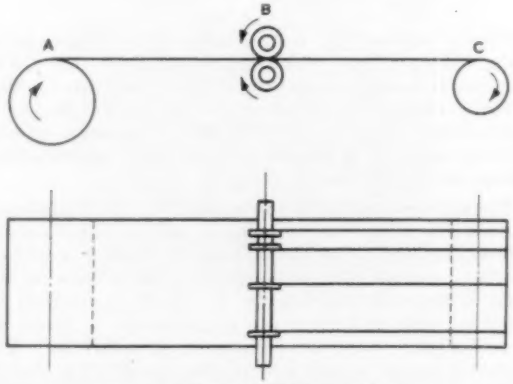



**Fig. 1—Gang slitting machine.**

operations. Depending on the design of core, the plates were either rectangular or a regular 45° trapezoidal shape.

By this method of production, the limits to which individual plates were produced depended on individual guillotine and press operations working from the same datum point or stop each time. With the general increase in transformer size, plates of up to 15 ft. long were being required regularly and the handling problems associated with this type of production began to approach the limit of human capability.

### Cutting the Plates

The new fully automatic core plate cutting machine combines in one operation the piercing of all holes or slots and the cutting of two plates per cycle of the machine. Provision is also made for grinding of edge burrs, if necessary. All dimensions are related to the theoretical centre line of the strip of material, i.e. the centre line of the core. This has the advantage of dividing possible inaccuracies in the width dimensions equally to both sides of the plate, and not to one side only as in the case of guillotine or press production where all measurements were made from one datum edge of the material. The possibility of variations in length dimensions occurring due to human error in the case of guillotine and press production have been eliminated by cutting both ends of each plate and punching all holes and slots in one operation of the machine while the strip of material is in tension.

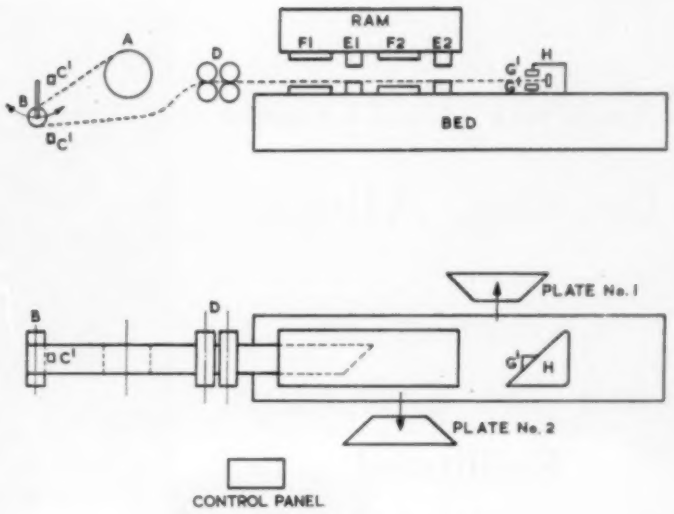



Fig. 2—Core plate cutting machine.

Fig. 2 shows the layout of this plant with its control equipment, the bed of the press being 30 ft. long and 4 ft. 8 in. wide. The machine is fed automatically to cut laminations two at a time, each 15 ft. by 36 in. wide and a special facility catering for laminations up to 47 in. wide has been incorporated.

The sequence of operations, having set all the tools, end, hole or slot forming, is first to load the de-coiler (*A*) with a coil of material of the width and grade required. With the machine under hand control, the material is fed round the swinging arm (*B*), through the feed rolls (*D*) until the leading edge is beyond the first end forming tool ($E_1$). The machine is operated by foot control and one set of holes or a slot is pierced by the piercing tools ($F_1$) and a 45° mitred end, formed by tool $E_1$. The piece of scrap material lying beyond $E_1$ is removed and the press switched to automatic control.

The automatic sequencing is now—feed rolls (*D*) draw material from the loop between *D* and *A*, passing it under the piercing and end forming tools. When the swinging arm (*B*) is pulled sufficiently far from the at-rest position, contact across the photo-electric cell (*C'–C'*) is made and the de-coiler (*A*) operated, thus supplying more material to the feed rolls. As the leading edge of the material interrupts the photo-electric cell (*G'–G'*) the rate of feed is cut from 200 to ½ ft./min. until the leading edge hits a micro-switch in the hydro-pneumatic press unit (*H*), when the unit operates and punches a small anchor hole in the material, the punch remaining through the material. The action of punching the anchor hole immediately opens one pair of the main feed rolls (*D*) and causes the other pair to reverse, thereby pulling out any ripples there may have been in the material.

This slow tensioning of the material continues until the electric clutch, through which the rolls are driven, starts to slip, when a hold-down ram in the feed roll unit (*D*) operates and holds the material in the tensioned condition. The reversing rolls return to the disengaged position and the ram operates, cutting and piercing two complete plates. As the ram rises all side stops are lowered and the piercing tool in the hydro-pneumatic press unit (*H*) is withdrawn, thus setting in operation the ejection mechanism which ejects one complete plate to the back and the other to the front of the machine, where they are automatically stacked on pallets. As ejection is completed, this cycle is repeated automatically. The machine is equipped with modern and completely adequate safety devices at all stages of operation.

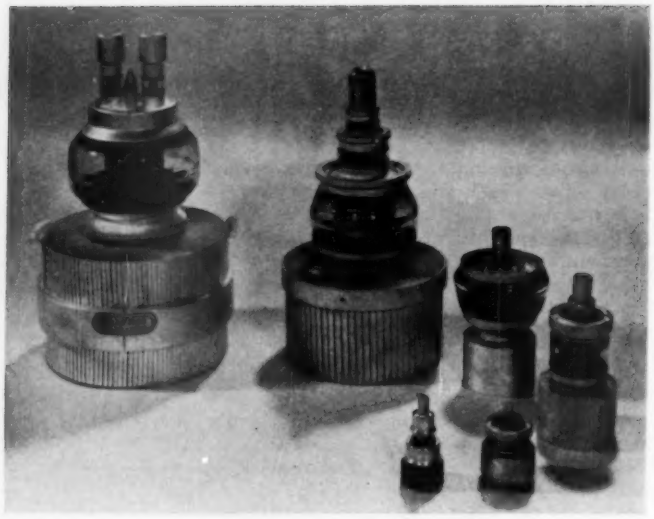
Dimensional and other details of this machine are as follows :—

| | |
|---|---|
| Overall length of plant | 60 ft. |
| Overall width of plant | 4 ft. 8 in. bed |
| Overall height of plant | 12 ft. |
| Method of control | Electronic-pneumatic-hydraulic |
| Weight of moving parts | 10 tons + 3 tons for tools |
| Total weight | 60 tons |
| Number of operators | Two |
| Range in plate size | From 15 ft. to 2½ ft. centre line length ; from 36 in. to 5 in. wide |
| Maximum number of holes | Unlimited |
| Maximum number of rows of holes | Unlimited |
| Range in hole sizes | ¾–2 in. diameter |
| Slot size | 2½ in. × 12¾ in. one per plate |
| Weight of end forming tools | 1½ tons each |
| Number of plates/hour | 360–480 |

*Continued on page* 144

# Special Purpose Brazing Alloys

## Economies in Time and Equipment Facilitated



*(Courtesy of Standard Telephones & Cables, Ltd.)*

**722 and 724 alloys are used in the construction of these V.H.F. transmitting valves.**

A range of special-purpose brazing alloys has been developed, opening a much wider field to brazing techniques. Many operations which hitherto entailed welding or mechanical assembly now lend themselves to brazing with resulting economies in time and equipment. For maximum strength in brazed assemblies, lap joints are normally recommended, and correctly designed joints will possess strength in excess of that of the parent metal. The choice of a brazing alloy of appropriate melting range can lead to assemblies of greater strength than can be obtained by welding, as the deletrious effects on the structure of the parent metal, arising from overheating during the welding cycle, may be avoided.

The range of special-purpose brazing alloys, available from the Baker Platinum Division of Engelhard Industries, Ltd., includes certain of the established silver and gold alloys and also the recently developed palladium-containing alloys. The properties and some of the applications for which particular alloys are most suitable are described below. In general these alloys offer three important advantages over conventional brazing materials :—

(*a*) strength at high temperature ;

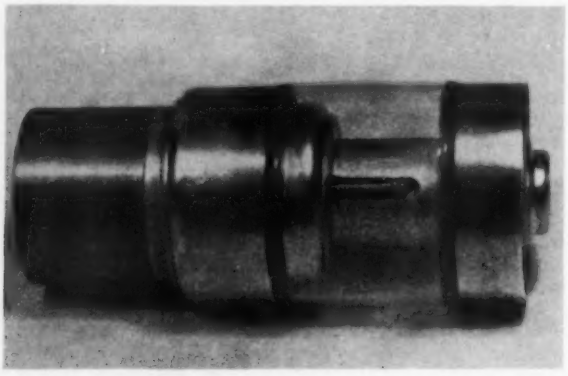
(*b*) low vapour pressure ; and

(*c*) certain materials which could not be brazed with conventional alloys can now be joined satisfactorily.

The following additional advantages are offered by the palladium-containing alloys :—

(*d*) erosion of the parent metals is reduced to a minimum and, as a result, thin sections may readily be joined ; and

(*e*) it has been found possible to join metallised ceramics directly to low expansion alloys without nickel plating the ceramic.



*(Courtesy of Ferranti, Ltd.)*

**The junction between the focus electrode and the support tube in this Klystron amplifier electron gun is brazed with 441 alloy.**

*Silver-Copper-Palladium Alloys*

The development of the palladium-containing brazing alloys has considerably widened the scope of brazing, opening the field to many new applications for high temperature and vacuum conditions and for joining difficult parent metals. Due to their low vapour pressures compared with the conventional silver brazing alloys, they are particularly useful in all vacuum applications, including electronic valve construction. The alloys have excellent flowing and wetting properties and penetrate exceptionally well into the spaces being filled. Nevertheless, the bridging qualities are such that, when the design permits, clearances of up to 0·020 in. may be filled successfully. This wide tolerance to joint clearance can represent considerable economies in final machining operations before brazing.

There is little attack on ferrous or nickel-containing alloys by palladium-containing brazing fillers. This is particularly advantageous when brazing thin materials, such as those used for honeycomb structures, heat exchanger parts, etc. Selection from the appropriate alloys in the range enables complicated components to be assembled by step brazing. Steps of approximately 50° C. (liquidus temperature) from 800° C.—1,100° C. are

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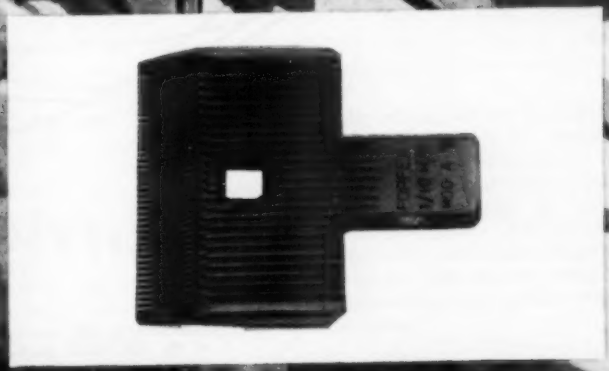

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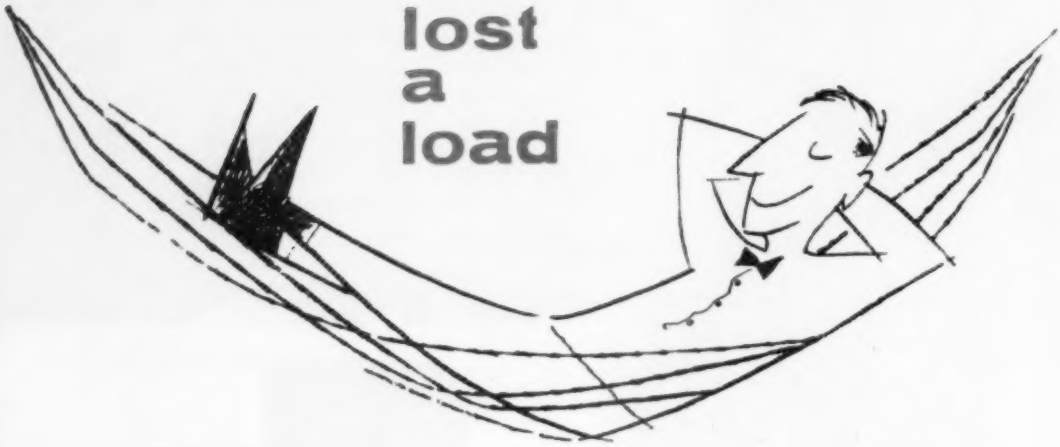

# of worries

(Hargreaves did) . . . . the day he sent for his copy of the HYPREZ book, and also received details of the new slow speed lapping machine and new HYPROCEL self adhesive lapping and polishing discs. Told him all about this latest method of fine grinding, lapping and polishing metals. (he has an *enquiring* mind) . . .

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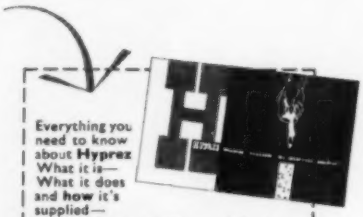

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DIAMOND **HYPREZ** COMPOUND

TABLE I—PHYSICAL PROPERTIES OF ENGELHARD SPECIAL-PURPOSE BRAZING ALLOYS

| Alloy Ref. No. | Alloy | Tensile Strength (tons/sq. in.) | Elongation (% on 10 in.) | Hardness (D.P.N.) | Specific Gravity at 20° C. | Resistivity (microhm/cm. cube at 20° C.) | Liquidus (° C.) | Solidus (° C.) | Typical Brazing Temperature (° C.) |
|---|---|---|---|---|---|---|---|---|---|
| 179 | Silver-Copper | 26 | 30 | 88 | 10·0 | 2·5 | 779 | 779 | 800 |
| 424 | Gold-Copper | 30 | 17 | 230 | 17·25 | 14·2 | 889 | 889 | 910 |
| 429 | " " | 27 | 38 | 112 | 15·2 | 13·9 | 915 | 905 | 930 |
| 441 | Gold–Nickel | 45 | 5 | 245 | 17·4 | 29·2 | 950 | 950 | 970 |
| 722 | Silver-Copper-Palladium | 29 | 23 | 90 | 10·1 | 3·9 | 810 | 807 | 815 |
| 723 | " " " | 31 | 22 | 75 | 10·1 | 6·0 | 852 | 834 | 860 |
| 748 | " " " | 32 | 25 | 140 | 10·3 | 9·9 | 898 | 876 | 905 |
| 724 | " " " | 30 | 20 | 120 | 10·4 | 9·6 | 900 | 850 | 905 |
| 725 | " " " | 33 | 15 | 185 | 10·5 | 14·3 | 950 | 901 | 955 |
| 718 | " " " | 14 | 28 | 80 | 10·6 | 4·7 | 1,010 | 970 | 1,015 |
| 719 | " " " | 22 | 30 | 85 | 9·4 | 15·0 | 1,090 | 1,080 | 1,095 |
| 279 | Copper-Palladium-Nickel-Manganese | 40 | 25 | 135 | 9·0 | 52·5 | 1,105 | 1,080 | 1,110 |
| 2,601 | Silver-Palladium-Manganese | 18 | 11 | 95 | 10·5 | 9·4 | 1,120 | 1,000 | 1,120 |
| 2,602 | " " " | 32 | 25 | 130 | 10·8 | 21·5 | 1,900 | 1,180 | 1,220 |
| 318 | Nickel-Manganese-Palladium | 55 | 7 | 330 | 8·4 | 18·1 | 1,120 | 1,120 | 1,125 |
| 288 | Palladium-Nickel | 50 | 30 | 224 | 10·3 | 31·7 | 1,237 | 1,237 | 1,250 |

available in the silver-copper-palladium group, and the range may be extended by using other special-purpose alloys.

Stress corrosion cracking occurs with many of the conventional silver-containing brazing alloys when brazing nickel-iron alloys (e.g. in glass-to-metal seals). The presence of palladium in the silver-copper-palladium alloys has been found to inhibit this effect and to confer increased resistance to oxidation and other forms of corrosion. For effective inhibition of stress corrosion when brazing low expansion alloys, a palladium content of not less than 10% is desirable. For this reason, alloys designated 724, 725, 719 and 748 (see Table I) are particularly recommended for such applications. The alloys do not form brittle compounds with most parent metals; hence, there is little danger of unexpected failures in service.

The silver-copper-palladium range of brazing alloys was developed originally to meet the special requirements of the radio industry. The primary aim was to produce a graded melting range to enable electronic valve assemblies to be fabricated by step brazing. Another important consideration was to provide alloys with vapour pressures lower than those in any existing range of silver brazing alloys and, therefore, particularly suitable for vacuum applications.

The comparatively low melting points of the silver-copper-palladium alloys have proved advantageous for brazing where the parent metals are susceptible to grain growth at higher brazing temperatures. Furthermore, in some applications, it has been found possible to combine brazing with heat treatment. Apart from their advantages when brazing conventional metals, other more difficult parent metals—including cobalt-base alloys, Nimonic alloys, tungsten, molybdenum, zirconium and beryllium—have been successfully brazed with silver-copper-palladium alloys.

*Silver-Palladium-Manganese Alloys*

These alloys have excellent creep resistance at elevated temperatures, and were originally developed to braze high-temperature, creep-resistant metals such as tungsten, molybdenum, heat-resisting steels, and cobalt-base and nickel-base alloys. Erosion of stainless steels and alloys of high nickel content is slight and these brazing alloys have been successfully employed for joining thin sections. This factor renders the alloys of particular value in the fabrication of heat exchangers. The palladium content of 2,602 alloy is higher than that of 2,601, which accounts for the difference in brazing temperatures and mechanical strengths. For the same reason, 2,602 alloy is used only when the higher resistance to creep is desirable. Due to the high brazing temperature, 2,602 alloy is not recommended for certain nickel-base alloys such as the Nimonics.

*Nickel-Manganese-Palladium Alloy*

318 alloy was developed as an alternative filler material to 2602 alloy. It has, however, a lower brazing temperature and higher shear strength combined with comparable stress life on joints tested at elevated temperatures. It finds applications in brazing high-temperature creep-resistant metals such as tungsten, molybdenum, heat-resistant steels and cobalt- and nickel-base alloys. 318 alloy is resistant to attack by molten alkali metals, and is thus of particular interest in applications not only for air-cooled gas turbines but for turbines cooled by liquid sodium. The alloy is of considerable interest for applications in the nuclear energy field owing to its freedom from silver and elements of high neutron capture cross-section. As in the case of the silver-palladium-manganese alloys, the erosion of stainless steels and alloys of high nickel content is minimised, and 318 alloy is, therefore, particularly suitable for joining thin sections in the fabrication of heat exchangers.

*Copper-Palladium-Nickel-Manganese Alloy*

279 alloy was one of the most recent to be developed and has found applications in the nuclear energy field, it being second only to 318 alloy in resistance to attack by the molten alkali metals. It is particularly suited to brazing stainless steel and nickel-base alloy components where the low degree of erosion encountered renders the alloy particularly suitable for joining thin sections. In common with 318 alloy 279 alloy is suitable for vacuum brazing, but is available in a far wider range of sizes than the former alloy.

*Palladium-Nickel Alloy*

288 brazing alloy is unique in its combination of high

strength at high temperature and excellent vacuum properties. This alloy has the highest palladium content of any of the palladium-containing brazing alloys, and better vacuum properties than any with comparable strength at high temperatures. It has been used for brazing high melting point materials, such as tungsten and molybdenum, for electronic applications. In this connection it may be employed as the first joint in a graded series, thereby extending the range of steps available with the existing silver-copper-palladium alloys. Thin sections of stainless steel may be brazed, and application has also been found in brazing metallised ceramics and cermets and in the nuclear energy field.

*Silver-Copper Alloy*

179 alloy is a long-established brazing alloy which, due to its excellent vacuum properties is used widely in the electronic valve industry. The flowing and wetting properties are exceptionally good. Because 179 is a eutectic alloy, it is not suitable for bridging large clearances. To some extent, 179 alloy is tending to be superseded by 722 alloy which shows certain important advantages, but, for step brazing, this silver-copper alloy provides a useful addition to the silver-copper-palladium alloys by extending the lower end of the melting point range. 179 alloy will braze nearly all parent metals satisfactorily, but when stress corrosion cracking is to be combated the silver-copper-palladium alloys will give improved results. Similarly, silver-copper-palladium alloys are to be preferred for brazing parent metals which tend to form brittle compounds.

*Gold-Copper Alloys*

Gold-copper brazing alloys have outstandingly good vacuum properties and, in this respect, are second only to palladium-nickel (288 alloy) and to gold-nickel (441 alloy). 424 gold-copper alloy, although not a true eutectic, has a single melting point and has the higher gold content: 429 alloy possesses a plastic range, and hence, is more tolerant to joint clearance. Both alloys exhibit extremely good resistance to all forms of corrosion and may be employed with a wide range of parent metals. The gold-copper alloys are finding a wide field of application where their relatively high cost is outweighed by their exceptional properties.

*Gold-Nickel Alloy*

441 alloy has the lowest possible melting point of any alloy in the gold-nickel series and, together with 288 alloy, has the best vacuum properties of any of the special-purpose brazing alloys described. Hence, it finds applications where the highest vacua are required. Due to its high gold content, 441 alloy provides exceptionally high resistance to all forms of corrosion. In addition to its exceptionally low vapour pressure, this alloy also possesses greater mechanical strength than the gold-copper alloys.

## Cutting Plates for Transformer Cores

(*continued from page* 141)

The plant has been in production since July, 1960, and has achieved the original objectives of producing core laminations to a higher degree of accuracy than previously, resulting in an increase in core efficiency. It has also overcome handling difficulties with consequent increase in productivity.

The machine was designed and developed by Ferranti engineers and manufactured to their instructions by A. Kinghorn & Co., Ltd., Todmorden, Humphries and Sons, Ltd., Poole, and The Norbury Engineering Co., Ltd., Hyde. Items of ancillary equipment have been manufactured by Ferranti, Ltd.

### Annealing and Insulating

One of the important requirements of cores built of cold rolled steel is to provide careful annealing of the laminations to relieve the stresses set up in the material during the cutting and punching processes. The continuous annealing plant installed in 1957 is another indication of the determination of Ferranti, Ltd. to use this material as efficiently as possible.

The conveyor-type stress relief annealing furnace, which is 120 ft. long and has an output of 0·5 ton per hour, has many advantages over conventional batch type furnaces. The annealing operation is carried out in an atmosphere of nitrogen, satisfactory annealing being assured by strict control over the operation of the plant and by regular checking of annealed samples for iron loss by the Epstein square method. With the continuous belt type furnace the temperature gradient across a lamination is lower, due to the exposed area of the charge being relatively greater and the heat transfer predominantly normal to the laminations. This results in a shorter annealing cycle and consequently reduced risk of contamination from the annealing atmosphere.

The core material as supplied by the manufacturers in coils is insulated on both sides with a very thin anneal-proof insulating coating applied by a special thermo-chemical process. After annealing, one side of each lamination is further treated with insuline (kaolin plus binder) in a modern plant to a controlled thickness.

## New Ford Blast Furnace

Ashmore, Benson, Pease & Co., Ltd., of Stockton-on-Tees, one of the companies in the Davy-Ashmore group, has just been awarded a contract by the Ford Motor Co., Ltd., of Dagenham, to construct a new blast furnace with a hearth diameter of 20 ft. It is a happy coincidence that this—the fiftieth modern blast furnace which Ashmore's have constructed in the United Kingdom and overseas during the past thirty years—comes from the same client who ordered their first, so many years ago. The original unit had a hearth diameter of 18 ft. 3 in., and astonished the industry by its performance; it held for at least twelve years every British record for output, and its economical coke consumption has only recently been rivalled by much later units. The new furnace is planned to go into production in the summer of 1962.

Additional factory premises in Wimbledon have been acquired by the British Rototherm Co., Ltd., Merton Abbey, London, S.W.19, the scientific instrument makers.

# NEWS AND ANNOUNCEMENTS

## International Galvanizing Conference

At the Sixth International Galvanizing Conference to be held at Interlaken from the 4th to the 9th June, 1961, twenty-three papers will be presented by experts from Europe, Canada, Australia and the U.S.A. Technical sessions on bath heating, the metallurgical aspects of the process, welding, and after-treatments for galvanized steel will be of interest to all galvanizers. In addition, there will be a session on works practice and informal discussions on management problems (of particular interest to jobbing galvanizers) and other special sessions on sheet, strip, and wire galvanizing.

In conjunction with the conference there will be works visits to jobbing plants in Switzerland and to strip, wire and tube galvanizing plants in Italy. Exhibitions of equipment and materials used in galvanizing and of applications for galvanized steel are also being arranged. Copies of the preliminary notice, which contains a registration form, may be requested from the Zinc Development Association, 34 Berkeley Square, London, W.1.

## Institute of Metals Medal Awards

The council of the Institute of Metals announces the following awards of medals for 1961 :

*The Institute of Metals (Platinum) Medal* to Major C. J. P. Ball, D.S.O., M.C., chairman, Magnesium Elektron, Ltd., in recognition of his outstanding services to the non-ferrous metal industries and, in particular, to the magnesium industry.

*The Rosenhain Medal* to Dr. P. B. Hirsch, of the Cavendish Laboratory, Cambridge, in recognition of his outstanding contributions in the fields of physical metallurgy and metal physics.

## " Aluminium in Architecture "

During the shooting of the prize-winning film " Cities of Light " by Centre Internationale de Developpement de l'Aluminium (C.I.D.A.), of which the Aluminium Development Association is a member, it was foreseen that much technical material would be filmed that would be of special interest to architects and builders. A.D.A. has, therefore, for their benefit, had such material made into a film under the title " Aluminium in Architecture." It is a 16 mm. colour film comprising two reels, each of 20 minutes duration, which can be used separately if required. It has been prepared for distribution in English speaking countries by British Films, Ltd., and the commentary is spoken by Richard Baker of B.B.C. Television.

The film records journeys made by Paul de Roubaix, the well-known cameraman of Paris, accompanied by an architect, to England, France, the U.S.A., Austria, Germany, Switzerland and Italy. It portrays trends in modern architecture and assesses the part aluminium is playing in its evolution. The film enables British schools to be compared with French ones, and American skyscrapers with their more modest European counterparts. It is interesting to note that whilst some countries continue to use their indigenous materials, such as marble, aluminium is being combined with them. At the same time curtain-wall construction with aluminium is being adopted in every country. Design of buildings is spectacularly free and effective. The manner in which advantage is taken of unusual sites is illustrated and a number of original ideas in applying aluminium will not escape the trained eye of the architect and builder.

Requests for loans of copies of " Aluminium in Architecture " should be made to The Aluminium Development Association, 33 Grosvenor Street, London, W.1. Tel.: Mayfair 7501.

## Cybernetics Congress

The third International Congress of Cybernetics, organised by the International Association for Cybernetics, will be held at Namur from 11th to 15th September, 1961. The programme will be arranged in five sections : (1) principles and methods of cybernetics ; (2) semantic machines ; (3) automation : technical aspects ; (4) automation : economic and social aspects ; and (5) cybernetics and life. Workers in this field wishing to present a paper to the Congress, should communicate with the Secretary of the " Association Internationale de Cybernetique, A.S.B.L.," rue Basse-Marcelle, 13, at Namur, Belgium, giving the title. Further information on the Congress can be obtained from the same address.

## Industrial Solvent Price Reduction

I.C.I.'s General Chemicals Division has reduced the U.K. prices of two important industrial solvents, trichloroethylene and perchloroethylene, the former by £1 per ton and the latter by £5 per ton. These reductions have been made possible by greater output following increased demand. When similar price reductions were announced for January 1st, 1960, I.C.I. disclosed plans for a £1 million extension to the solvents plant operated by the General Chemicals Division at Runcorn, Cheshire. This project is now well advanced and production is expected to start in the summer. Greater production capacity will enable I.C.I. to satisfy the growing demand for these two solvents for metal-degreasing, dry-cleaning, and extraction. As a result, it is hoped that further reductions in price will become possible.

## Park Gate Development

Tube Investments, Ltd., announced in October a scheme by their subsidiary, The Park Gate Iron and Steel Co., Ltd., for the development of a new integrated works on a site adjacent to the existing Park Gate works near Rotherham. The aim was to bring the new works into operation early in 1964. It has now been decided that the development should be phased to make use of the group's existing supplies of cold pig iron for the time being. Initially the new works will include the steel-making department, the blooming mill followed by a continuous billet mill and, on the finishing side, the continuous narrow strip mill. Hot metal for the Kaldo process in the new melting shop will be drawn from the company's existing blast furnaces at Park Gate. The

Park Gate steel furnaces will draw cold pig iron from Renishaw (another subsidiary of T.I.) and from outside sources. The company's total ingot production at 800,000 tons a year will be only a little less than that earlier contemplated.

The cost of this initial phase of the development is estimated to be of the order of £33 million compared with the estimate for the whole scheme of about £58 million. This phasing of the scheme has the consent of the Iron and Steel Board. It is still the aim that the new works should ultimately form a modern integrated plant including ironmaking facilities based on home ore and that they should accommodate further modernisation of the existing works.

### Micro-Tensile Testing

TUBE INVESTMENTS announces an agreement with Techne (Cambridge), Ltd., for rights to manufacture a micro-tensile testing machine developed by the Tube Investments Research Laboratories at Huxton Hall, near Cambridge. The machine now deals with single crystal " whiskers " often too small to resolve with the naked eye. It employs a torsion balance to apply loads of 1 mg. to 400 g. to specimens with cross-sectional areas down to one 5,000 millionth of a square inch, and it measures by optical and mechanical means extensions in the specimen from a few Ångstrom units to 15 mm. It can readily be adapted for tests in compression, tests in special atmospheres, and for thin film testing.

## Personal News

FOUR new directors have been appointed to the board of Fletcher Miller, Ltd., the Hyde manufacturers of cutting fluids and industrial lubricants: they are MR. J. R. BICKERTON, chief chemist at the Hyde plant; MR. J. BIRCHENOUGH, works manager at the Hyde plant; MR. R. A. MILLER, divisional sales manager in the North London division; and MR. S. V. TILLEY, senior technical representative in the Midlands and South Wales. In addition, the board have approved the appointment of MR. D. W. HOWE as their Northern area manager, engineering division.

MR. P. R. ARMITAGE has been appointed manager of the traction division of The General Electric Co., Ltd., in succession to MR. W. D. MORTON whose promotion to assistant general manager of the Witton Works was announced recently.

WICKMAN, LTD., announce that MR. H. B. MORRIS, secretary, has been appointed to the board of the company.

MR. C. SMITH has been appointed assistant general manager of the Ore Mining Branch of The United Steel Cos., Ltd. He has been succeeded as group manager, underground mines, by MR. F. HARRISON, who was previously assistant group manager, underground mines.

MR. A. G. CLEGHORN, general manager, Blackheath Works, Birmingham and MR. W. H. WENTWORTH PING, general sales manager, have been appointed special directors of Firth-Vickers Stainless Steels, Ltd.

MR. E. E. BLAKE, who has been with Kodak, Ltd., for more than fifty years, has relinquished his appointment as a director of the company, but will continue to serve as a consultant on matters relating to motion picture film business. MR. S. C. SMYTH has relinquished his appointment as financial comptroller, and will relinquish his appointment as a director on March 31st. To fill the vacancies arising on the board, MR. N. A. BRICK has been appointed a director, with effect from January 1st, 1961, and MR. W. F. TAYLOR is to be appointed a director with effect from April 1st, 1961. Mr. Brick has recently been appointed deputy manager of Harrow factory, and Mr. Taylor, until recently deputy-comptroller, became comptroller of the company on January 1st, following the resignation of Mr. Smyth.

SHELL-MEX and B.P., Ltd., announce the appointment of MR. G. RICHARDSON as manager, industrial fuels department. This is a new department formed from the present fuel oil department and the company's subsidiary, Shell-Mex and B.P. Gases, Ltd. This merging of the fuel oil and liquefied petroleum gas interests brings together the sale of these products to industry and commerce generally.

GEORGE KENT, LTD., have appointed MR. R. KENT to be deputy chairman, and MR. W. MAY to be assistant managing director of the company; and have also appointed as a director, MR. J. G. VAUGHAN managing director of the Charterhouse Finance Corporation.

IN order to make room for promotion, SIR WALTER BENTON JONES, Bt., has retired from the board of Davy-Ashmore, Ltd. and MR. M. F. DOWDING has been appointed a director. Mr. Dowding is general manager of the machinery division of Davy and United Engineering Co., Ltd., one of the Davy-Ashmore subsidiaries. As agreed in principle at the time of the Davy-Ashmore merger, MR. C. E. WRANGHAM, formerly chairman of Ashmore, Benson, Pease and Co., Ltd., and of P.G. Engineering, Ltd., has resigned from the boards of these subsidiaries and MR. M. A. FIENNES has been appointed chairman in his place. Mr. Fiennes is the managing director of Davy-Ashmore, Ltd.

## Obituary

WE regret to record the death of the following:

SIR ARTHUR CROFT, chairman of Crofts Engineers (Holdings), Ltd., who died at his home, Buckstone Hall, Rawdon, near Leeds, at the age of seventy-four. Sir Arthur joined the business as an apprentice just sixteen years after it had been founded by his father on a capital of £50. When the business became a private limited company in 1907, Sir Arthur was appointed a director, and on his father's death in 1920 he became joint chairman, followed by governing director in 1936. When the public company was incorporated in 1948, he became chairman and managing director. He retired just shortly after completing fifty years' service with the company in 1953.

MR. C. VERNON-ROBERTS, western district manager of The Calor Gas (Distributing) Co., Ltd., who died in hospital at Wrexham, on 31st January, 1961, at the age of fifty-three. Mr. Vernon-Roberts was a member of the company for eighteen years, and prior to making his home in Ruthin, Denbighshire a year ago, he had served for four years as south-western district manager, with his home at Budleigh Salterton, Devon.

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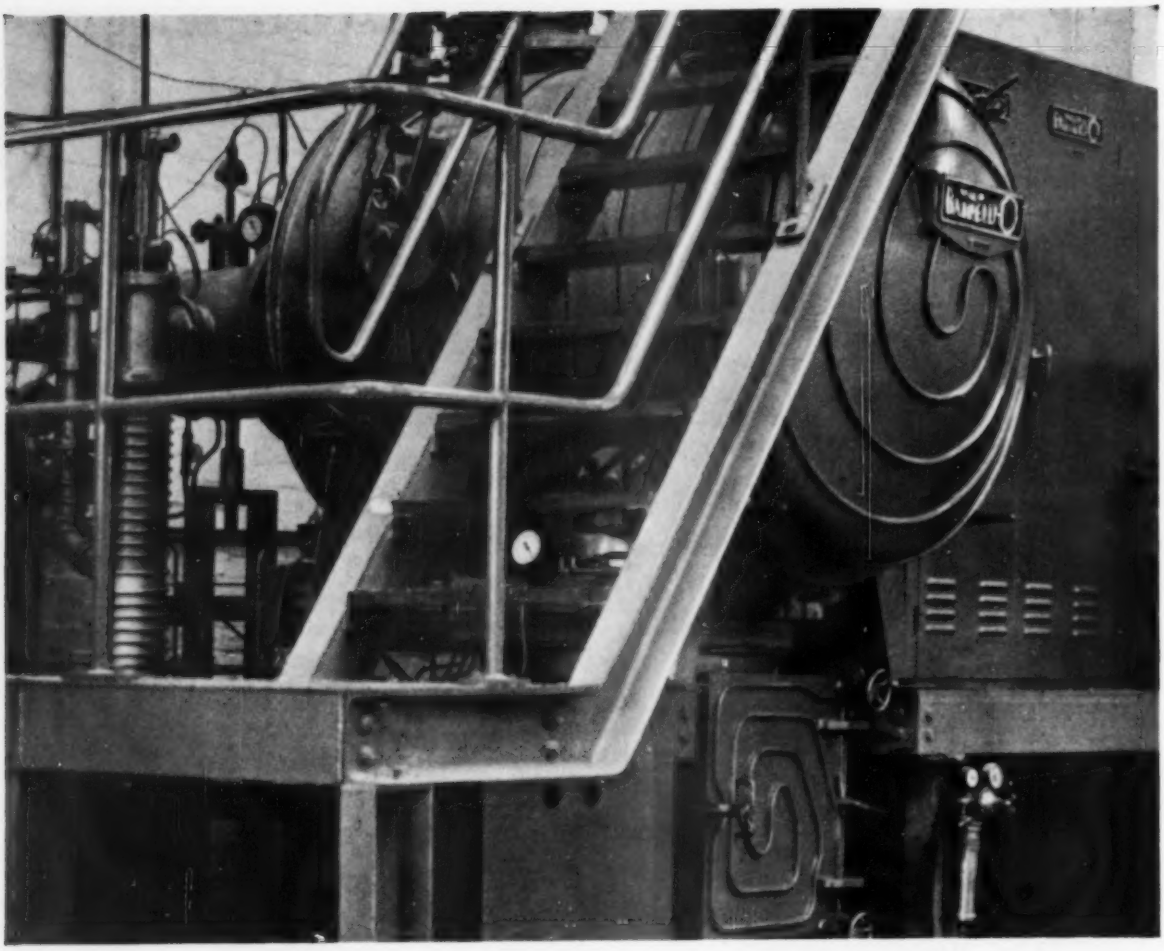
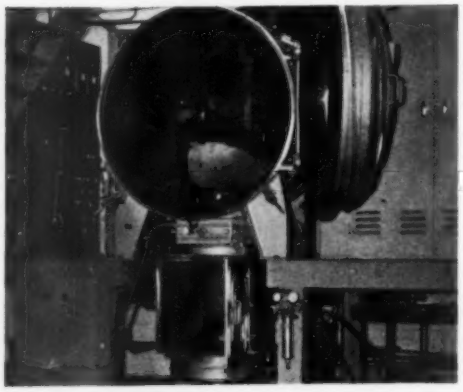


# *Vacuum Induction Furnaces at Bristol-Siddeley Engines Ltd.*

Increased output of jet engine components. That is briefly the result of installing this 50 lb. (molten steel) capacity Wild-Barfield-NRC vacuum induction melting furnace at Filton. Bulk charging and mould locks enable semi-continuous production to be maintained. In fact, the weekly output of this one equipment is greater than that of five vacuum arc furnaces used for similar work. If you have a vacuum application, remember that the experience of Wild-Barfield covers the design and manufacture of all types and sizes of vacuum furnaces.



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# RECENT DEVELOPMENTS

## MATERIALS : PROCESSES : EQUIPMENT

### Laboratory Flow Control Valve

To be used in flow systems as an on/off control where the maximum flow rate is 525 ml./min. at 60 cm. head of water, the Grundy solenoid valve, is a cylindrical glass valve with a metal cored glass plunger, actuated by a concentric solenoid from a mains control unit. The glass valve has an overall length of 110 mm. and is cylindrical, being 70 mm. long by 16 mm. in diameter, with riffled extensions to accommodate 5 mm. diameter tubing. The cylinder contains a metal-cored glass plunger with a ground glass plug at one end which sits into the ground surface at the constricted outlet of the valve. The glass valve is mounted through the solenoid which is housed in a metal casting, 90 mm. in diameter, 57 mm. long with an integral bosshead to accommodate rods of up to $\frac{1}{2}$ in. in diameter.

The control unit, housed in a sheet metal case $6\frac{3}{4}$ in. wide by 9 in. in depth, is a step-down mains transformer tapped at 12 V. with three circuits for controlling simultaneously (up to) three solenoids for operation on 200/250 V. at 50 cycles A.C. The case is fitted with a white inclined front panel carrying a push button on/off switch with an indicating light for each solenoid, a mains on/off switch and a pilot light. The control panel and solenoid are housed in a synthetic hammer enamel finished case.

*Griffin & George, Ltd., Ealing Road, Alperton, Middlesex.*

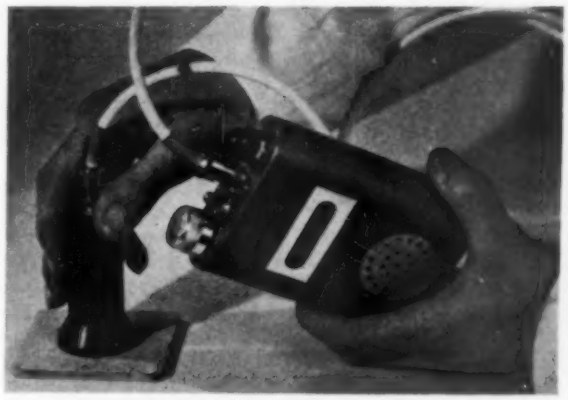
### High-Temperature Torch

A NEW high-temperature torch—the plasma-jet—designed by British Oxygen Research and Development, Ltd., is particularly suitable for applying coatings of high melting point or reactive material by spraying. Successfully deposited are high melting point materials such as zirconia, alumina, and titania; refractory and reactive materials including tungsten, tantalum and silicon; chemically-resistant materials such as titanium and stainless steel; and wear-resisting materials like tungsten-carbide and nickel-chromium-boron alloys. Possible uses for the plasma-jet include the coating of components such as rocket nose cones, jet engine tail tubes and gas turbine blades with refractory and wear-resistant materials. Other possible uses include coating of steel parts with chemically-resistant materials such as titanium and stainless steel and the application of hard wear-resistant coatings.

*British Oxygen Research & Development, Ltd., Deer Park Road, Wimbledon, London, S.W.19.*

### Audio Thickness Gauge

WITH the extensive present day use of the metal spraying process for the protection of steel structures, the question of inspection and quality control becomes more urgent. Because thickness is an important part in the protective value of sprayed metal coatings it is essential that this should be adequately checked. The introduction of an entirely new type of measuring instrument goes a long way to reducing the problem. This instrument, which has been designed specifically for sprayed zinc and aluminium coatings, enables large areas to be checked rapidly.



The principle of its operation is based upon an exploring head which may be moved quickly over the coated surface. The instrument, having been set to indicate a minimum thickness, gives an audible warning of areas which are below the required thickness. Accurate test specimens are used to set the gauge to any desired thickness between 0·002 in. and 0·012 in. The set is completely portable, fully transistorised and the miniature operational battery has a life of over four months. It is unaffected by magnetic fields or stray magnetism. Whilst the exploring head is designed for flat surfaces, adaptors are being designed to enable the unit to measure curved surfaces and tubes.

*Metallisation, Ltd., Barclays Bank Chambers, Dudley, Worcs.*

### Continuous Level Indicator and Controller

AFTER extensive field trials in various industries, Thomas Industrial Automation, Ltd., are now marketing a new instrument known as the Levelrator which not only gives continuous indication of the contents of silos, tanks, hoppers, etc., but it will also operate visual and/or audible alarms. The equipment uses one electrode only for both continuous measurement and control. Alarm points can be set to operate over the full length of the electrode to suit the particular application.

The electrode system can be of the rigid variety for a small vessel and the flexible type when the depth of the container exceeds 6 ft. The limitation of length of electrode is really dependent upon the particular application, but electrodes are available up to 60 ft. in length. The high or low level control points are completely independent of the indicating instrument, and the relays are operated by a specially designed electronic circuit. The long term stability and reliability of this equipment are claimed to be exceptionally high, and to be virtually unaffected by normal mains and temperature fluctuations.

The control unit, consisting of a stabilised power

supply, alarm relay circuits, and built-in calibrating instruments, is housed in a specially designed cast iron or sheet steel weatherproof case, and can be situated up to 150 ft. from the electrode head unit. The built-in calibrating instrument has a scale length of 2¼ ft., graded in 2% divisions, and can, if necessary, be used as a local indicator.

Remote indicators can be supplied to customers' requirements, and sited anywhere on the plant. The Levelrator can be supplied in multipoint units which allow centralisation of all the control and indicating meters. Meters can also be supplied for fixing to existing panels and control desks.

*Thomas Industrial Automation, Ltd., Station Buildings, Altrincham, Cheshire.*

## Improved Nickel Plating System

THE outdoor resistance of chromium plated components can be substantially improved by using a dual coating of nickel beneath the chromium plate, the dual coating consisting of a deposit of semi-bright nickel followed by a deposit of bright nickel. The Efco-Udylite Bi-Nickel system that has been introduced by the Electro-Chemical Engineering Co. Ltd., consisting of N2E sulphur-free semi-bright nickel followed by 66 bright nickel, gives good results in marine and mobile exposure and also in accelerated corrosion tests. Ductility and freedom from pitting are two advantages of the Efco-Udylite N2E deposit, which can be applied to any of the basis metals which are normally plated with bright nickel, such as suitably polished steel articles, copper plated zinc-base die castings, brass components, etc. High levelling, high lustre, good ductility are characteristics of the Efco-Udylite 66 deposit and the degree of adhesion obtained between the two deposits is excellent. The overall cost of the Bi-Nickel system is lower than that of other dual nickel processes in current use.

*The Electro-Chemical Engineering Co. Ltd., Sheerwater, Woking, Surrey.*

## Closed Circuit Television

WITH a view to reviving the interest of those who have previously regarded closed circuit television as too costly, Nash and Thompson, Ltd., have recently introduced a new industrial television camera selling at £275, thus making possible a complete minimum installation for as little as £335. The Nashton equipment is simple to operate and the installation can easily be carried out by the user. No special control unit is required, all the power supplies being in the camera which is only 13¼ in. × 7¼ in. × 7¼ in. A standard commercial 405 line television receiver is used as the monitor. This provides the great advantage of using local servicing arrangements to reduce shut-down time.

The total equipment consists of the camera, which is connected by a co-axial lead to the aerial socket of the monitor receiver. The cost of the camera is only £275 while the monitor can range from about £60 to £100 according to the size of the screen. Various lenses, tripods, junction boxes etc. are available for use with the equipment.

The Nashton camera uses a Vidicon pick-up tube and is normally supplied with one standard 1 in. *f*1·9 lens, having a horizontal angle of 28°, providing a field of view of 10 ft. of 5 ft. wide by 3½ ft. 9 in. high. A 12-ft. mains lead is provided to supply the 240 V. 50 c./s. mains to the camera. The signal output is fed via a co-axial socket on the rear to the aerial socket of the receiver/monitor. The camera can be tuned by an internal preset capacitor to any of channels 1 to 5 in Band I. The controls on the rear of the camera are width, target, focus, height and beam plus a mains on/off switch and fuse.

The maximum distance between the camera and the monitor varies from 400 ft. to 2,500 ft. according to the type of cable and the number of monitors used. If longer runs are required a booster or distribution amplifier can be provided according to the application.

The camera has a modern appearance and two-tone colouring to blend into its surroundings and has been designed as a rugged unit for industrial applications. Printed circuits are used to ensure long life and reliability.

*Nash and Thompson, Ltd., Oakcroft Road, Chessington, Surrey.*

## Pulse Polarograph

THE pulse polarograph developed at Harwell to overcome the limitations of square wave polarography when applied to irreversible reductions, has the marked advantage of being capable of operation with base electrolytes 100 times more dilute. The instrument, now available commercially as the A1655 pulse polarograph,

is capable of producing both normal and derivative polarograms, it being possible to detect reversibly and irreversibly reduced ions at concentrations of $10^{-8}$M and $10^{-7}$M, respectively. Effects due to residual current, and to high concentrations of ions reducing at a lower potential, have been largely eliminated. The A1655 is in console form with 12-in. eye-level chart recorder, thermostatically controlled electrode system, and self-contained hydrogen generator for deoxygenation.

*Southern Instruments, Ltd., Frimley Road, Camberley, Surrey.*

# CURRENT LITERATURE

## Book Notice

### THE USE OF ALUMINIUM IN RAILWAY ROLLING STOCK

Proceedings of a symposium held in May 1960, 152 pp., including many illustrations. Published jointly by the Institution of Locomotive Engineers, 28 Victoria Street, London, S.W.1., and The Aluminium Development Association, 33 Grosvenor Street, London, W.1. 42s.

THE development of aluminium alloys and their ever-increasing application to railway rolling stock led to the Aluminium Development Association inviting the Institution of Locomotive Engineers to hold jointly with them a symposium on the use of aluminium in railway rolling stock. This was held at the Institution of Mechanical Engineers on 27th May 1960 and about 260 members and guests attended.

The symposium comprised two sessions—a morning session when five papers on design and construction were introduced and discussed, and an afternoon session which was devoted to eight papers on operation and service experience. These thirteen papers were contributed by authors from Canada, France, East Africa, Germany, the United States and the United Kingdom : they have been reprinted in the present volume together with the complete discussion and the authors' replies.

The design and construction papers dealt with such aspects as the properties of aluminium used in rail vehicles ; general aspects of design in aluminium alloys ; stress determination in coach frames by electronic computation ; the crumbling of tubular structures under impact conditions ; and the use of aluminium in the construction of railway vehicles. In the second session there was an assessment of economies obtained with lightweight rolling stock and an account of experience with light alloys in subway rolling stock. The remaining papers related experiences with aluminium alloys in general railway rolling stock in the countries mentioned in the preceding paragraph.

The papers were of such wide interest that they promoted very lively discussions and communications from some twenty contributors. The presentation of these along with the original papers make this volume one of considerable interest to all engaged in the design manufacture and operation of railway rolling stock as an up-to-date survey of the knowledge gained by the experience of some of the leading rolling stock builders, university engineering departments and railway organisations in the U.K. and overseas.

## Trade Publications

THOS. FIRTH & JOHN BROWN, LTD., have been making forged steel rolls for more than half a century, and this experience, together with the collaboration of the Brown-Firth Research Laboratories, has enabled the company to establish the most suitable composition, heat treatment and hardness of a roll for a particular set of operating conditions. In a new illustrated brochure (Publication No. 222/1) are discussed the design, manufacture and properties of fully-hard rolls, semi-hard rolls, cogging rolls for steel bars and billets, and rolls for special purposes, the last group including leveller rolls, pinch rolls, tension rolls and rolls for the Sendzimir cold mill and planetary hot mill. Further sections are concerned with maintenance and reconditioning, and with the ways in which failure can occur, the appearance of typical modes being illustrated.

IT is some sixteen years since John Holroyd & Co., Ltd., published a brochure on Holfos bronze. The new developments which, controlled by steady research have taken place in the company's foundries, together with the increase in the machine shop facilities, have made a new edition of this book a necessity. Its sixty extensively illustrated pages present the history, development and applications of Holfos bronze. This material as first known was produced by chill casting under scientific control. Later, casting in a rotating mould by a special process was used to produce Super-Holfos bronze. These are not, however, the only casting processes used by the company : they still retain adequate capacity for hand or machine moulded bronze sand castings, and have also adopted the newer shellmoulding and continuous casting techniques, each process having its place within the organisation.

" BUILT BY DAVY-UNITED " is the title of a 92-page book illustrating by typical examples the current range of rolling mill engineering at Davy-United. It is not, of course, possible to include a full description or individual illustrations of all the varied rolling mill plant installed in recent years ; rather does the book seek to present a visual impression of the design and productive capacity which Davy-United now disposes to meet the requirements of the metal industries. The type of plant featured, include rolling mills and auxiliaries for both ferrous and non-ferrous metals ; continuous processing lines ; lubrication and hydraulic systems ; rolling mill instrumentation ; and railway wheel plant. Finally there is a section outlining design and production capacity at Sheffield, Glasgow and Middlesbrough.

" THE HARVEY TEAM " is the title of an illustrated brochure issued by G. A. Harvey & Co. (London), Ltd., which has been produced for circulation to customers all over the world who may only know of the company through the department normally contacted. The booklet, therefore, gives an overall account of the activities of the company in heavy and light fabrication, sheet metalwork, steel furniture, perforated metal, wire work and weaving, and galvanising.

THE new Ultrasonoscope catalogue, available from Ultrasonoscope Co. (London), Ltd., is designed not only to set out the comprehensive range of equipment available, but also to be a valuable fundamental reference book for the newcomer to the field of ultrasonic non-destructive testing. More than half the space is devoted to the basic principles of ultrasonic testing and descriptions of some of the techniques used for the more common applications.

WE have received from Morgan Refractories, Ltd., a leaflet dealing with the products of their associate company, the Douglas Firebrick Co., who manufacture a range of bricks and special shapes made from their

Ayrshire deposits of aluminous clays and high alumina, sillimanite, bauxite and fused alumina materials from other sources. These products are detailed in the new leaflet.

THE main function of a priming paint for iron and steel is to protect the metal if corrosion and breakdown of top-coats occur. Croda, Ltd., have recently issued a technical data sheet on their P.P.138 priming paint in which the active pigment is calcium plumbate, which is both an anodic and a cathodic inhibitor.

"REFRACTORY SUSPENDED CONSTRUCTION" is the title of Reprint No. 51, issued by the Incandescent Heat Co., Ltd. In this paper, which was originally presented to a joint meeting of the Society of Furnace Builders and the Society of Glass Technology, Mr. W. S. Sinclair discusses the essential features necessary for an efficiently designed suspended roof.

TUBE INVESTMENTS, LTD., have recently issued an illustrated brochure describing the wide variety of extended surface tube now being made by their subsidiary companies. This type of tube is finding important applications in the oil, chemical and power producing industries.

IN THE first issue of the George Kent, Ltd., publication, *Instrument Engineer*, which appeared in April, 1952, there was started a series of articles entitled "A History of Flow Measurement by Differential Pressure." The last of the series was published in October, 1959, and the whole series has now been reprinted as publication 1010 with the title of "A History of Flow Measurement by Pressure-Difference Devices." This is available from the company's publicity department, at Luton, price 10s.

BASED upon a lecture given by Mr. L. G. W. Palethorpe, the company's chief metallurgist, an article on "The Use of Controlled Atmospheres in the Heat Treatment of Metals" is the principal feature of the December issue of the *Wild-Barfield Heat Treatment Journal*. Also included are an account of electric bell furnaces for heat treating stainless steels, vacuum melting plant at the Bristol Siddeley Filton works, and details of a new air dryer recently introduced from the United States.

A number of modifications have recently been made to the range of Holmes-Connersville positive air blowers Type RBS resulting in improved performances. These modifications are fully described in Publication No. 85, obtainable from W. C. Holmes & Co., Ltd., Huddersfield.

THREE recent furnace leaflets issued by the General Electric Co., Ltd., of England, deal respectively with roller hearth furnaces, induction heating furnaces and high temperature furnaces with hydrogen atmosphere. The induction heating furnaces described are produced under the terms of an agreement between the General Electric Co. and the British Geco Engineering Co., Ltd., covering design, manufacture and sale of induction furnaces. The high temperature furnaces, suitable for heat treatment at temperatures up to 2,500° C., are manufactured in this country under an agreement with the Austrian company—Metallwerk Plansee A.G.

To mark the 150th anniversary of the founding of the company, J. & J. Dyson, Ltd., of Stannington, Sheffield, have produced a 48-page illustrated book describing their products. Although the company still makes standard fire bricks and ladle bricks, it has established a reputation as a producer of casting pit hollow-ware for the steel industry. Following sections dealing with raw materials and technical service facilities, details and illustrations of the various products form the main section of the book.

IT is claimed that Inco-Weld A electrodes and filler wire are the first welding materials ever to be specifically designed for joining dissimilar metals. A leaflet, obtainable from Henry Wiggin & Co., Ltd., details the properties of welds obtained using these materials.

A NEW publication from High Duty Alloys, Ltd., is concerned with the Hiduminium 400 series of aluminium-base formable thermal neutron shielding materials. These consist of boron carbide, of suitably fine mesh size, evenly dispersed in a fully wrought aluminium matrix clad on both sides with high purity aluminium. Production is based on a technique whereby boron carbide particles are uniformly suspended throughout molten aluminium.

COMPLEMENTARY to the Nimonic series of heat resisting alloys, Henry Wiggin & Co., Ltd., have developed a Nimocast series of alloys which combine high temperature strength and scale resistance and are suitable for many applications involving the use of cast materials. They are similar to, and in some cases identical with, the corresponding Nimonic alloys, as far as composition is concerned. A publication available from the company describes the applications of these materials—mainly in aircraft gas turbines.

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# Books Received

"The Brittle Fracture of Steel," by W. D. Biggs. 420 pp., inc. author and subject indexes; 242 diagrams and illustrations. London 1960. Macdonald and Evans, Ltd. 70s. net.

"Materials for Nuclear Engineers," edited by A. B. McIntosh and T. J. Heal. 373 pp., inc. index; numerous diagrams and illustrations. London 1960. Temple Press, Ltd. 75s. net.

"Techniques of Non-Destructive Testing," by C. A. Hogarth and J. Blitz. 216 pp., inc. index: numerous diagrams and illustrations. London 1960. Butterworth & Co. (Publishers), Ltd. 40s. net.

"A History of Metallography," by C. S. Smith. 291 pp., inc. appendices, bibliographic notes, acknowledgments and index; 110 diagrams and illustrations. Chicago 1960. University of Chicago. 68s. net.

"Engineering Metallurgy, Part II, Metallurgical Process Technology," by R. A. Higgins. 404 pp., inc. index; many diagrams and illustrations. London 1960. The English Universities Press, Ltd. 25s. net.

"Embrittlement by Liquid Metals," by W. Rostoker, J. M. McCaughey, and H. Markus. 162 pp., inc. index; numerous diagrams and illustrations. New York 1960. Reinhold Publishing Corporation. 64s. net.

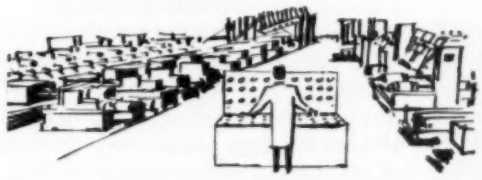
"Cermets," edited by J. R. Tinklepaugh and W. B. Crandall. 239 pp., inc. bibliography and index; numerous diagrams and illustrations. New York 1960. Reinhold Publishing Corporation. 76s. net.

"The Extrusion of Metals," by C. E. Pearson and R. N. Parkins. Second edition, revised. 336 pp., inc. index; numerous diagrams and illustrations. London 1960. Chapman & Hall, Ltd. 45s. net.

# Electric Motors & Controls-2

Control equipment must enable the motor to be operated effectively, to obtain maximum productive efficiency of a given machine. An outstanding advantage of individual electric drives is the flexibility of control available. Control equipment may be manual, semi-automatic or fully automatic, and includes gear for the following operations:

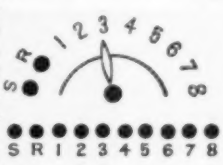
(a) Starting
(b) Speed Control (this subject will be dealt with in Data Sheet No. 16)
(c) Reversing
(d) Stopping
(e) Switching off automatically if operating conditions become abnormal
(f) Isolation of motor and control equipment from the supply.



Every application of power has its own particular control requirements—and they are legion. Below are featured four uses of electric motors and their controls; they are given only as examples and represent but a small fraction of the whole picture.

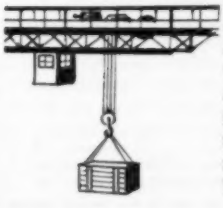
### *Turret-lathe Control*

Various speeds are required for different tools, and it is possible to arrange, for instance, for a four-speed headstock, forward and reverse, incorporating a power-operated pre-selector speed change. By using a two-speed double-wound motor, eight speeds forward or reverse are obtainable. A dial on the headstock is set to the required speed and when a knob in the centre of the dial is pressed, the power-operated mechanism changes the speed instantly.



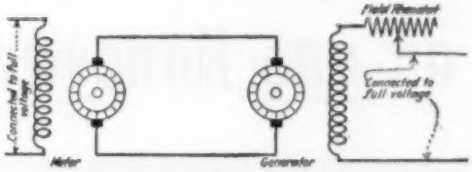

### *Crane Control*

This is a form of control which must be flexible yet completely foolproof. It is, for instance, possible to arrange for motor switching to be performed by contactors in response to movement of the crane driver's master controller which has a number of notches, each of which is associated with a particular set of contactors for acceleration, speed control, reversing and braking. If the controller is moved quickly from the 'off' position to the 'last point lowering', the rate of acceleration is limited automatically by the relays. These also govern the retardation in order to prevent a heavy descending load being stopped too suddenly. This is just one of the ways in which electric control mitigates the hazards of crane operation.



### *Planing-machine Control*

Another example of motor control for machine tools is that for planing machines. For general workshop machining, the Ward-Leonard controlled motor, with a speed range of 10 to 1, gives a rapid and smooth reversal of the table travel and is ideally suited for short-stroke work. Two arrangements of Ward-Leonard control are available, the 3-machine set with generator, exciter and driving motor, and a specially designed 4-machine set with an additional auxiliary exciter. With the 3-machine set the control




equipment can include magnetic time relays which automatically adjust a regulator to strengthen the motor field at the instant of reversal and therefore greatly increase the accelerating torque. The auxiliary exciter of the 4-machine set automatically provides 'field forcing' on the generator; in other words, the power input to the motor is increased to give more accelerating torque at the instant of reversal.

### *Automatic Control*

The control equipments described incorporate automatic features which help considerably towards obtaining safe and efficient operation of the driven machine, but much still depends on the human element. Braking equipment, for instance, cannot always become effective until an operative has taken some action. In an emergency this physiological time lag which delays the initial action will also delay the final effect. Fortunately it is often practicable to employ devices, which will be described in other Data Sheets, to 'observe' any abnormal condition and immediately and automatically to initiate the braking system.

Particular attention should be paid to the positioning of controls. When a machine, or group of machines, requires a large number of push buttons and, in some cases, instruments, etc., the controls can be grouped on a desk with a mimic diagram, located in a position where the operator has full view of the work.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2. TEMple Bar 9434.

They can offer you excellent reference books on electricity and productivity (8/6, or 9/- post free)—'Electric Motors and Controls' is an example.

E.D.A. also have available on free loan within the United Kingdom a series of films on the industrial uses of electricity. Ask for a catalogue.

7915

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Replace shorting plug unit on special input terminal board inside the instrument.

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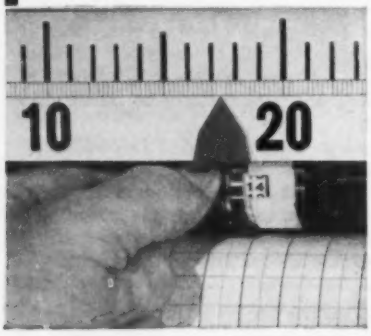
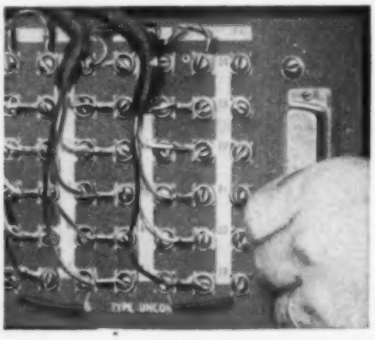
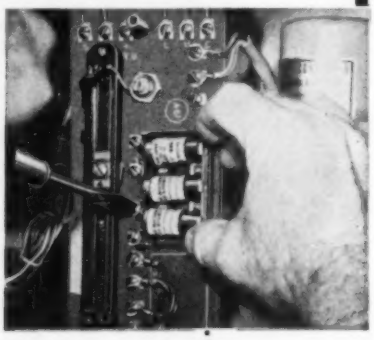
*Different detectors can be compensated for by introducing new input terminal board.*





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INSTRUMENTS AND MATERIALS
MARCH, 1961 Vol. LXIII, No. 377

# Edge Preservation During Metallographic Polishing

By J. T. N. Atkinson and C. A. Godden

*Naval Research Establishment, Dartmouth, N.S., Canada*

*A technique for mounting metallurgical specimens using metal flake fillers in the plastic is described. The mountings obtained give good edge preservation when the metallic specimens are covered by coatings of varying hardness such as paint, corrosion films and electroplates. Illustrations of results obtained are included.*

EDGE preservation during polishing of metallurgical specimens often presents a real challenge to the metallographer, particularly with samples involving thin layers of widely differing hardness, such as anodised or electroplated layers on aluminium or paint films on steel. Of the known methods of polishing, use of diamond abrasive,[1] with possible final use of magnesium oxide, preserves sample flatness best. Even here, however, slight rounding of sample edges occurs due to faster cutting of the plastic mount, and may be objectionable at magnifications of ×500, or more. Means were therefore sought to reduce the difference in cutting rate at the sample edge by incorporating a suitable filler into the plastic mount.

Admixtures of various mineral and metallic powders to the normal Bakelite mounting powder were studied; it was found that a flake metallic powder of the same metal as the sample in question was most suitable. The mounting powder should be finely ground (minus 120 mesh), the flake should be free of stearic acid, and the two should be intimately mixed. Suitable proportions depend on particle size distribution; for mounting aluminium specimens 2·5 parts by weight of aluminium flake to 7·5 parts by weight of Bakelite, and for copper specimens 3·5 parts by weight of copper flake to 6·5 parts by weight of Bakelite, were successfully employed for the particular powders available.

Somewhat higher than normal mounting pressures (*ca* 5,000 lb./sq. in.) are advantageous; the sample, inserted in the mixed powder, should be brought up to flow temperature and then the full pressure applied rapidly. The loosely compressed mixture, originally a thermal insulator, rapidly becomes conductive, and the sample develops an excess pressure as it expands while coming up to press temperature. A modest increase can be observed on the press pressure gauge, but, as can be seen from Fig. 1 the greater part of the increased pressure is effective only in the immediate vicinity of the sample. This results in an exceptionally hard and firm mounting around the sample periphery, and in improved sample flatness, even with the diamond abrasive procedure. Fig. 2 shows a nickel-plated copper sample mounted in copper-flake-filled Bakelite and electrolytically etched in 1% hydrochloric acid. The advantages of the technique are seen by the preservation of several small areas of nickel at the bottom of the large pore *B*: these would have been lost by ordinary mounting and polishing methods. Fig. 3 shows oxide film formed on aluminium in water at 200° C. It can be seen from the figure that the outer boundary of the oxide film is sharp and well preserved.

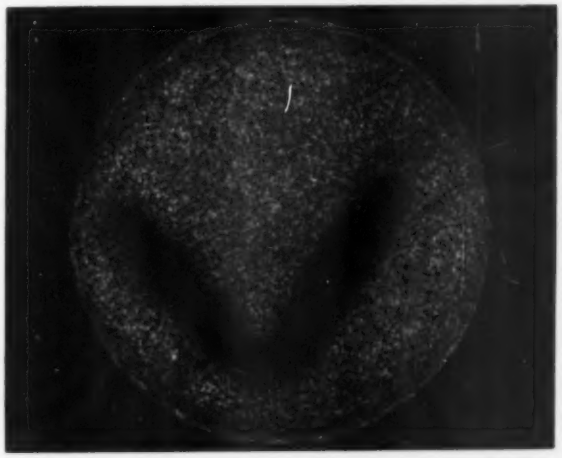


**Fig. 1.—Nickel-plated copper specimen mounted in copper-flake-filled Bakelite, showing compression area surrounding specimen. ×2·5**

A somewhat similar technique can be applied to casting resins, such as epoxies. However, it is not possible to add sufficient flake metal by direct means; it is therefore necessary to coat the sample initially with a low viscosity epoxy resin using vacuum impregnation if necessary on account of surface porosity, etc. The coated sample is then dipped in metallic flake, and the coating is allowed to harden. The treated sample is then mounted in a medium viscosity resin containing the maximum amount of metallic flake to retain pouring ability. Samples

1 L.E. Samuels, *J. Inst. Met.*, 1952, **81**, 471–78

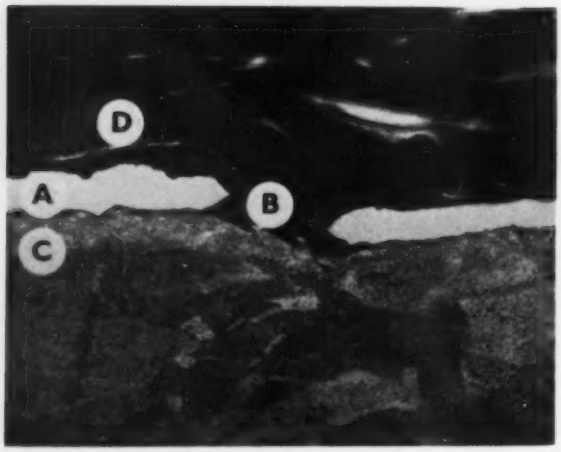



**Fig. 2.—Nickel-plated copper specimen mounted in copper-flake-filled Bakelite showing : A nickel plating ; B intrusion of plastic in defect ; C substrate of copper ; and D copper flake filler. ×520**

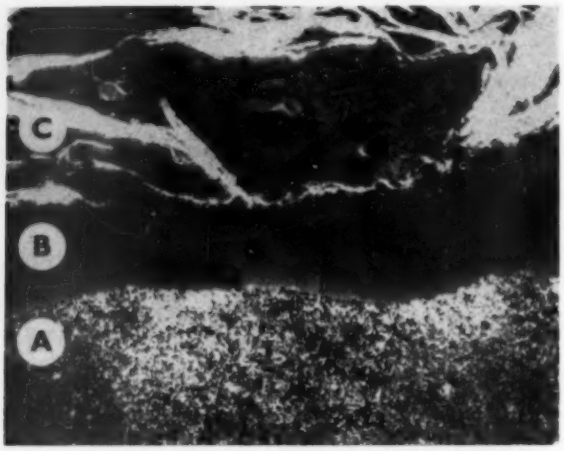



**Fig. 3.—Oxide covered aluminum specimen showing : A substrate of aluminum ; B oxide layers ; and C aluminum flake filler. The sharpness of the outer face of oxide film is clearly seen. ×700**

produced thus show a moderate improvement in final edge preservation relative to unfilled epoxy mounts, though the results are not so good as with the pressure mounting technique given above.

Use of dissimilar metal powders as plastic fillers is generally unwise, because of possible galvanic effects during the final polishing and etching stages. Electrolytic polishing is particularly convenient, since the typical pressed sample (1 in. diameter × 0·5 in. long) shows a resistance of about 2 ohms. Choice of plastic is limited only by the choice of the polishing and etching procedures, or by compatibility with the sample if paint coatings are to be examined in cross section.

### Acknowledgment

This work was part of Defence Research Board Project D-12-75-10-35. The authors wish to thank the Chairman of the Defence Research Board for permission to publish this work. The assistance of Mr. R. V. Smith is acknowledged in performing part of the experimental work involved.

## Kent's Italian Associate

FOLLOWING the acquisition by George Kent, Ltd., of 51% of the share capital of the Tieghi Co., of Milan and Lenno, a new company has been formed—Kent-Tieghi S.p.A.—which has purchased the whole of the assets and goodwill of the Tieghi Co. Kent-Tieghi have modern and well equipped works at Lenno on Lake Como, and head offices in the centre of Milan. Their products at present include recorders and controllers for flow, pressure and temperature of liquids and gases (both circular and rectangular chart) using pneumatic control systems, and supported by an extensive series of primary elements, relays and actuators. More recently, a range of miniature pneumatic recorders and controllers, and force-balance transmitters, has been put into quantity production. The company also holds an exclusive import and distribution franchise for the American Conoflow range of pneumatically operated control valves.

## Cambridge Instrument Expansion

WORK is now well advanced on another large modern building at the Cambridge Instrument company's factory in Chesterton Road, Cambridge. The new building, which will be similar in appearance and joined at one end to the company's new research laboratories, will consist primarily of two floors supported at first floor level by a series of reinforced concrete pillars. The top floor will house testing, assembly and wiring departments, and the first floor will be devoted to enlarged production space for the company's Microscan x-ray analyser and to works offices. The area beneath the first floor will be almost wholly taken up by parking space and a loading bay with gantry and platform. An important feature is a double-decker bridge that will connect the building to existing production departments and provide additional space for a calibration room and cloakrooms.

The building, which is expected to be ready for occupation in July, adds 16,000 sq. ft. of floor space to the 20,000 sq. ft. provided by the research laboratories, which were opened by Lord Adrian in October, 1959. The mode of construction will give a clear area on all floors uninterrupted by columns or beams, and extensive use is being made of new materials and techniques. In addition, the building will be fully air-conditioned in order to provide an exceptionally high standard of cleanliness and the best possible conditions for those who will work there. The contract for the new building is being carried out by Messrs. J. Jarvis and Co., to the design of the architects, Edward D. Mills and Partners.

## Morgan Refractories for Denmark

THE Dutch motor vessel *Carebeka* was recently chartered by Danish buyers to lift a cargo of Tri-Mor high temperature castable refractories, manufactured by Morgan Refractories, Ltd., of Neston, Cheshire—a member of the Morgan Crucible group. The consignment, worth £20,000, is destined for use instead of firebricks in the lining of two large power station boilers in Denmark.

# Exhibits of Metallurgical Interest at the Physical Society Exhibition

*(continued from page 102 of the February issue)*

### Strip Surface Finish Inspection

TINPLATE and cold rolled strip need to be inspected during manufacture for surface defects or blemishes. At high line speed this can no longer be done by the unaided eye. The factors involved in rendering the fault visible may not be explicitly appreciated, and the exhibits on the stand of the British Iron and Steel Research Association demonstrated techniques employed in developing instrumental aids to visual inspection, as well as for studying the feasibility of fully automatic high speed inspection.

*Contrast Enhancement.*—Bright tinplate has high specular reflection with little scatter. Surface defects show up as bright areas in a dark field, when viewed at an angle a few degrees off specular, and the high contrast attainable by correct choice of angle as well as appropriate setting of brightness and contrast controls was demonstrated in one of the exhibits. Also demonstrated was the way in which the image of a substantial length of strip can be built up by presenting narrow sections of the strip consecutively to a television camera, associated with a long afterglow monitor.

In the practical case of examining strip at high speed, the image can be arrested by a rotating or oscillating mirror arrangement in front of the television camera. The camera looks at the strip through a mirror slot transverse to the direction of motion of the strip; the effect of the image arresting mirror is to convert the view "seen" by the camera to the appearance of a static plate behind a moving slot. By storing the images successively disclosed through the slot, a picture of an extended sample of strip can be built up, viewed over its whole area under identical conditions of lighting, which are those obtaining in the narrow region viewed through the fixed slot. The demonstration simulated this effect by viewing a fixed curved sample through a moving slot, the image arresting mirror being omitted.

*Photoelectric Scanning.*—To demonstrate this technique, three strips of tinplate with typical surface defects and one narrow strip of prime material were stretched over a drum rotated at approximately 700 ft./min. surface speed. The photocells receive scattered (i.e., off specular) light from the tinplate surface and their output current increases when defects traverse the illuminated field. The signals are amplified and passed through biased discriminators, which are set to a level slightly higher than the signal due to prime sheet. Signals in excess of the discriminator level from three adjacent channels are summated and filtered by an R.C. network before being presented to a further discriminator which makes an "accept—reject" decision. The purpose of the R.C. filter is to equalise the amplitude of signals from localised (e.g., scratch marks) and extended defects of comparable severity.

### Ultrasonic Probe Manipulator

Experience has shown that inspection by the immersion technique often requires the ultrasonic beam to be directed other than normally into the material being tested. In addition components with irregular shape may require the probe to be set at quite acute angles. At the same time the probe may have to be lifted, lowered or rotated about its axis.

The latest addition to the manipulator range of Ultrasonoscope Co. (London), Ltd., is usually supplied fitted to a supporting gantry, the construction of which is flat and can be dimensioned to suit customers' existing inspection tank. Displacement along and across the gantry is achieved by means of handwheel operation through lead screws. Scales are provided for measuring probe distance moved, marked in inches and tenths or centimetres and millimetres. Further subdivisions can be made on the handwheels giving increments down to one hundredth of an inch or one tenth of a millimetre.

A handwheel control mounted on the front of the manipulator allows a movement of 0·2° to be recorded in the rotation of the search probe about a vertical axis. Backlash of this movement is virtually non-existent. Probe movement from a position approximately 20° to the vertical with the crystal face towards the couplant surface through 200° can be obtained by the use of a ball handle at the top of the manipulator. Thus, in conjunction with a 180° rotation about the vertical axis, a 320° rotation is possible about the horizontal axis. Provision is also made for the probe crystal face to be aligned parallel to the specimen with the rotation dial readings set to zero.

### Special Ceramics

Modern industrial needs are usually for an all-round product, having a number of useful properties, rather than one special advantage. This is particularly true in the new field of "special ceramics." Special ceramics, capable of working at very high temperatures, form a promising field of materials which is being developed rapidly. They are needed today for work in nuclear reactors, in rockets, in high temperature thermocouples, and in chemical and metallurgical plants.

Five years ago the potentialities of the field had barely been considered, but on the D.S.I.R. stand this year the British Ceramic Research Association had on show five new high temperature ceramics. Three of the materials (silicon nitride, silicon carbide and boron nitride) are now being produced on pilot plant scale at the Research Association's laboratories in Stoke-on-Trent. Sample products are being supplied to prospective users for practical trials—after which it is certain that production will be taken up commercially in this country. The other two (aluminium nitride and boron phosphide) are still in the research stage and were shown for the first time at the Exhibition.

Silicon nitride is a very strong hard ceramic that can be used at temperatures at which most metals would soften, melt or oxidise. It withstands sudden changes of temperature and does not shrink during firing: this

latter fact is a great advantage in making articles of complicated shape by machining the product in a partially fired state before final firing. Otherwise machining of the finished product would need diamond tools. Chemically inert, silicon nitride is highly resistant to attack by many molten metals and non-metals and can be used as a container for these. Silicon nitride articles have a further advantage in that they can be prepared by slip casting. This is done by pouring a suspension of silicon powder into a porous mould and allowing it to settle into a thick coating on the inner surface of the mould. The cast material is then fired in nitrogen and the result is a strong, hard product having the dimensions of the mould.

Silicon carbide has an excellent history as a high temperature material, but the strength of the bond holding the carbide grains together has limited its use. Now a technique has been evolved by the B.C.R.A. which produces a self-bonded silicon carbide with about ten times the strength of the older types. The new material is highly resistant to erosion by the hot exhaust gases of rockets. Among its other possible applications are as internal pump parts for handling corrosive liquids and molten metals, high temperature resistance thermometers, heaters for high-temperature furnaces, and structural parts for nuclear reactors.

Boron nitride has a great advantage in that it can be shaped by normal machine tools. Its mechanical properties resemble those of graphite, yet it is an excellent electrical insulator. As such it may find application as a spacer in electronic valves and in waveguides, and in high temperature furnaces. Since it is resistant to attack by many molten metals and semiconducting materials, it may be used as crucibles or crucible liners; and the low packing density of its well crystallised powder offers qualities as a thermal insulator. Other possible applications are as control rods in atomic reactors.

Aluminium nitride is a strong, hard, electrically insulating material with properties and uses similar to silicon nitride. It may prove superior to silicon nitride in contact with molten aluminium. For example, it may be used as a container material or a thermocouple sheath. Boron phosphide, still in the research stage, may be used for transistors.

### Measuring Hydrogen Content of Steels

Cracking and other forms of strain produced in steel may be caused by the amount of hydrogen it contains. This may be equally true of manufactured plate or a simple welded joint. A great deal of subsequent damage could be avoided if it were possible to assess quickly the amount of hydrogen in a given sample and take action to remove it. The British Welding Research Association has, in the last year, perfected a new rapid technique for measuring the amount of hydrogen dissolved in steels, and the prototype apparatus, which has been used during this period without failure, was shown for the first time at the Physical Society Exhibition.

Until now the determination of hydrogen in steel has usually been made by heating a sample to about 600°–700° C. in a high vacuum system. Then the gas has been drawn out in a similar way to that used for the dehydration of materials, by a combination of heat and vacuum. This system has had a number of disadvantages: the apparatus is expensive and fragile, and an analysis may take up to two hours. The new technique takes about fifteen minutes. It uses a carrier gas principle in which argon, an inert gas, is passed over a sample of steel heated in a furnace. The gas which is produced is swept along to a hydrogen sensitive cell from which the result can be plotted directly on to an electrical graph recorder. This system is accurate to as little as 1 p.p.m. of hydrogen.

### Filament Type Paramagnetic Oxygen Detector

The characteristics of the new filament type paramagnetic oxygen detector shown by Cambridge Instrument Co., Ltd., are largely complementary to those of the annulus type, which has given successful and continuous service for many years. The latter instrument, although more suitable for applications where more than 1% of hydrogen is present is affected by carbon dioxide and requires levelling before use. Conversely, the filament type detector is comparatively insensitive to carbon dioxide and more suited to conditions associated with vibration or change in level (such as on sea-going vessels), thus widening considerably the range of application for instruments of this type.

In the new oxygen detector, two similar heated filaments are mounted in cavities in a metal block, and each is open to a stream of the gas mixture to be analysed. One of the filaments is situated in a strong magnetic field. Each filament forms one arm of a bridge network in such a way that a difference between the filament resistance values causes unbalance in the bridge. The dissimilar magnetic environments of the filaments lead to a difference in oxygen concentration round them and to a related difference in their effective temperatures and resistances. This causes an unbalance in the bridge indicative of the amount of oxygen present in the gas stream. The bridge output can be displayed on indicators or recorders in the conventional way and can also be used to operate ancillary controls or alarms.

The detecting cell contains no moving parts and the instrument is robust and compact. Particular care has been taken in the design to minimise anomalous gas circulation within the detecting cell. Normal fluctuations in ambient temperature, sample flow rate and pressure, and mains voltage produce errors not exceeding 1% full scale. Sensitivities corresponding to a full scale deflection of down to 1% oxygen can be provided for most gas mixtures.

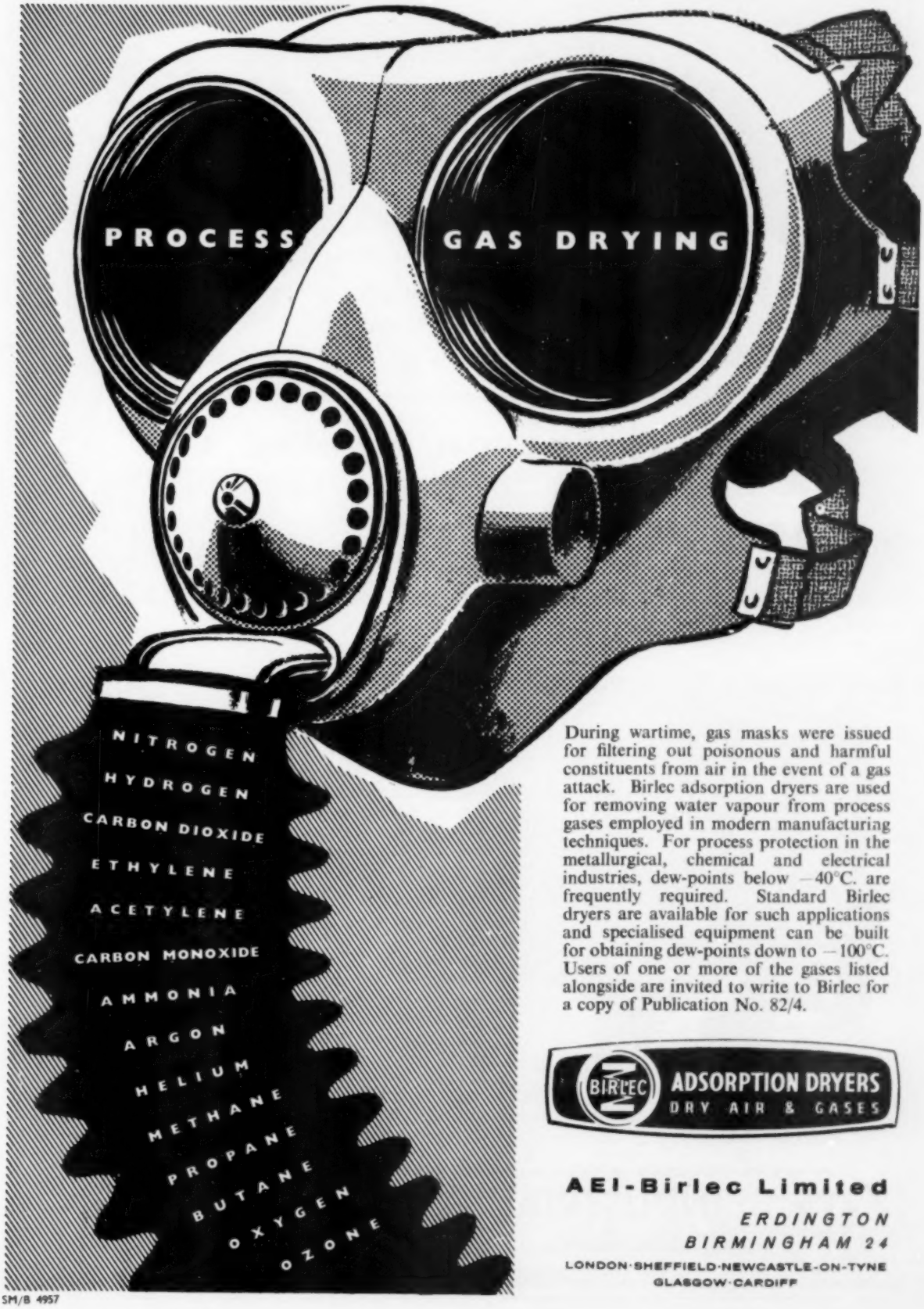
*(To be continued)*

---

THOS. FIRTH & JOHN BROWN, LTD., have placed an order with W. C. Heraeus G.m.b.H., Hanau, through their U.K. agents, Fleischmann (London), Ltd., for a vacuum arc-melting furnace to produce steel ingots up to 7 tons. The furnace is to be used for remelting steel electrodes under vacuum, the electrodes being cast by conventional methods. This process results in considerable reduction in non-metallic inclusions and gases (oxygen, nitrogen, hydrogen), and in improved grain structure of the ingot.

---

ALUMINIUM, LTD., and Antonio Vernocchi S.A. of El Palomar, Buenos Aires, announced recently that agreement had been reached for the purchase by Aluminium, Ltd., of a majority interest in the Vernocchi company. Antonio Vernocchi S.A. has been a manufacturer of aluminium foil since the early 1930's.

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During wartime, gas masks were issued for filtering out poisonous and harmful constituents from air in the event of a gas attack. Birlec adsorption dryers are used for removing water vapour from process gases employed in modern manufacturing techniques. For process protection in the metallurgical, chemical and electrical industries, dew-points below −40°C. are frequently required. Standard Birlec dryers are available for such applications and specialised equipment can be built for obtaining dew-points down to −100°C. Users of one or more of the gases listed alongside are invited to write to Birlec for a copy of Publication No. 82/4.

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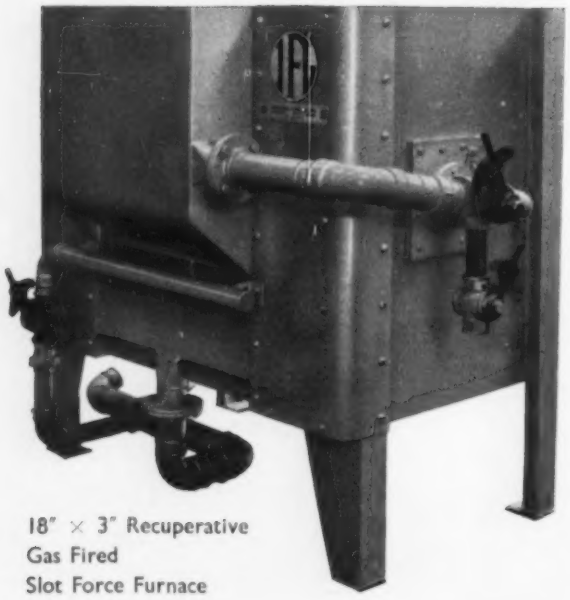

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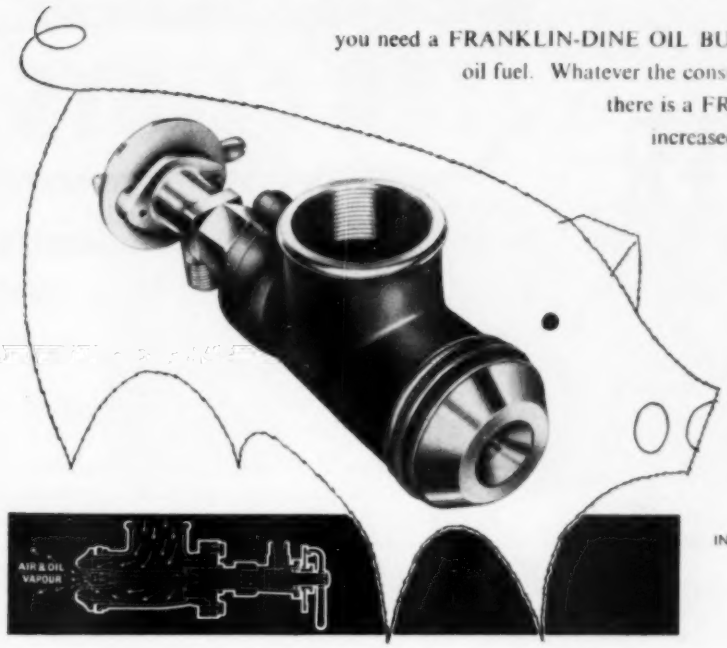


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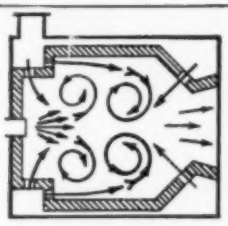

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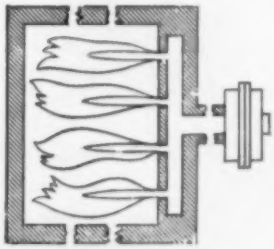

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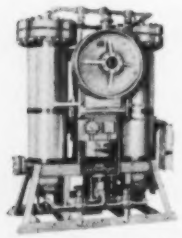

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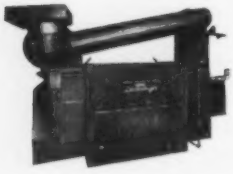

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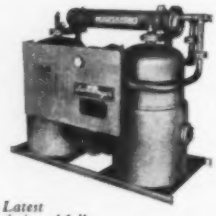

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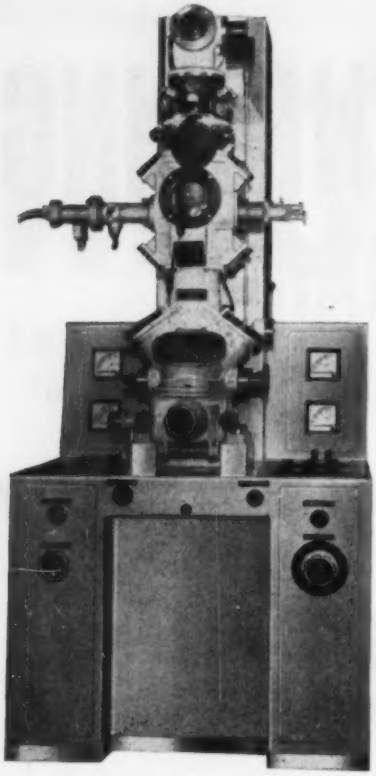

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GRADUATE Demonstrator (male) in Metallurgy required by Royal Military College of Science, Shrivenham, Berks. Teaching at University level. To assist in supervision of students' laboratory work and research. Extensive well-equipped laboratories. Personal research towards higher degree encouraged. Qualifications: 1st or 2nd class degree or equivalent. Salary £754–£910. Commencing salary allows credit for approved post-graduate experience and National Service. Superannuation under F.S.S.U. Appointments normally for 3 years, but may be extended. Quarters for single man; house for married man. Forms from Ministry of Labour, Technical and Scientific Register (K), 26, King Street, London, S.W.1, quoting reference F.76/1A.

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# CLASSIFIED ADVERTISEMENTS

## SITUATIONS VACANT—*continued*

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of the

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**1. SENIOR LABORATORY TECHNICIAN ELECTRO CHEMIST**

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**2. ELECTRO-PLATING TECHNICIAN**

The successful applicant will work as assistant to the Chemist in charge, but will be expected to work on his own initiative to a large degree.

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Letters of application, giving full personal particulars together with present salary should be sent to Box No. ME.107, "Metallurgia," 31, King Street West, Manchester, 3.

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# CLASSIFIED ADVERTISEMENTS

## SITUATIONS VACANT—*continued*

RESEARCH

METALLURGISTS, PHYSICISTS AND CHEMISTS

are invited to apply for appointment to the Staff of the Development and Research Department Laboratory

of

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BIRMINGHAM

These vacancies, resulting from continuing expansion, occur in sections of the Laboratory dealing with high temperature creep-resisting alloys, alloy steels, powder metallurgy, corrosion, electrochemistry, welding, physical methods of analysis and X-ray crystallography and general studies of the structure and properties of alloys.

The work of the Laboratory covers a very wide field of ferrous and non-ferrous metallurgy and the most advanced equipment is available to aid research. Members of the staff have personal responsibility for the work they conduct or supervise and every opportunity is provided for the publication of results.

Vacancies exist both for men with experience in particular fields of metallurgical or allied research and for graduates without research experience. Salaries will be appropriate to qualifications and experience.

Pension and assurance schemes are in operation and, in appropriate cases, assistance can be given for housing. Applications, which will be treated in confidence, should give details of age, qualifications and experience. They should be addressed to The Research Manager, D. and R. Dept., The International Nickel Company (Mond), Ltd., Thames House, Millbank, London, S.W.1. Please mark envelope "Confidential L.88E."

METALLURGISTS AND ELECTRICAL ENGINEERS required in a modern expanding company for development work on specialised iron, iron nickel and copper alloys used mainly in the electrical industry. Vacuum melting is extensively employed. The location is south of London and housing may be made available for a suitable man. A minimum qualification of degree, L.I.M. or H.N.C., is required. Applications, giving details of age, qualifications and experience, to The Research Manager, Telcon Metals, Ltd., Manor Royal, Crawley, Sussex.

NORTHAMPTON COLLEGE OF ADVANCED TECHNOLOGY, LONDON

DEPARTMENT OF APPLIED CHEMISTRY

METALLURGY SECTION

ASSISTANT LECTURER IN METALLURGY, GRADE B

Continued expansion of the section requires an Assistant Lecturer with graduate or equivalent qualifications to specialize in either Heat Treatment or Metallography.

Good facilities are available and a suitable candidate would be encouraged to pursue research for a higher degree (internal) of London University.

Salary—on scale £850 to £1,300 p.a. according to age and experience.

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WHITEHALL ROAD, LEEDS, 12

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B. HAYDN WILLIAMS,

*Director of Education.*

ROYAL TECHNICAL COLLEGE, SALFORD

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Applications, giving the names of two persons to whom reference can be made, should be sent to the Registrar, Royal Technical College, Salford, 5, Lancs., from whom further particulars may be obtained, by 15th April, 1961.

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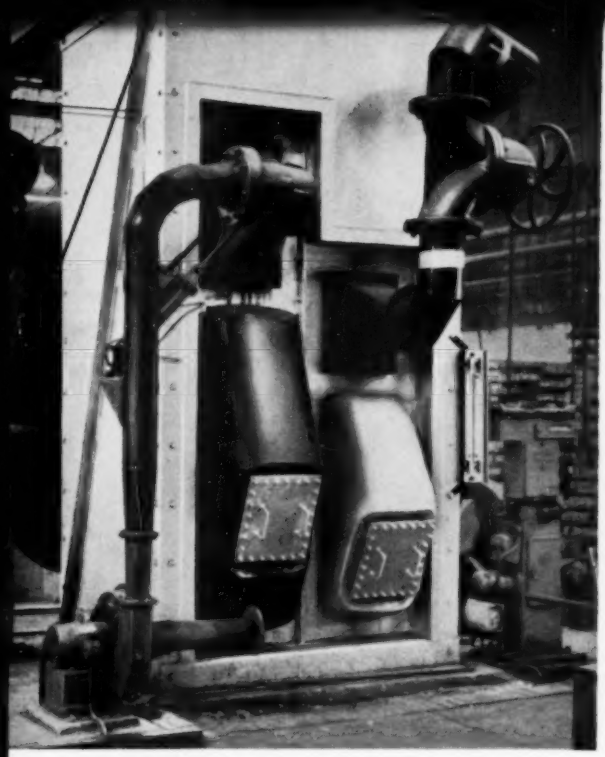

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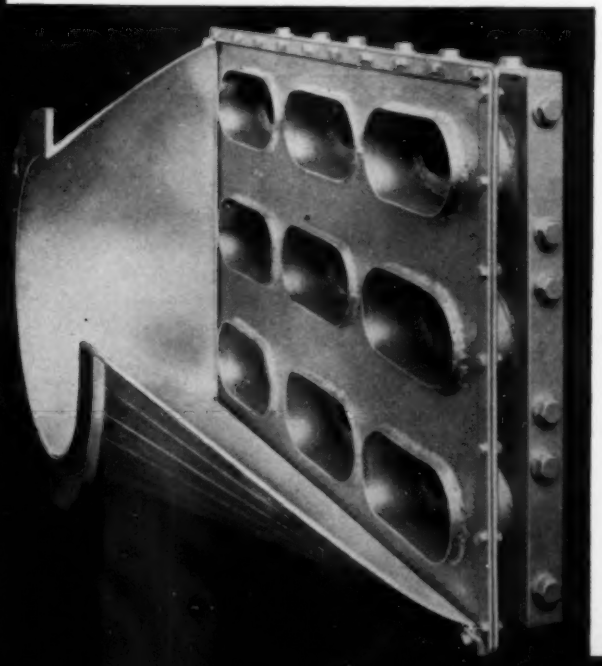

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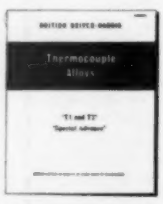


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